Back pain: measurements of spine deviations and balance; associated risk factors and preventive approaches in children and adolescents (9 to 19 years old).

Academic thesis submitted as a partial fulfilment of the requirements for obtaining a doctoral degree in Physiotherapy, from the Faculty of Sport of the University of Porto, under Decree-Law No. 74/2006 of 24 March, as amended by Decree-Law No. 65/2018 of 16 August.

Supervisor: Leandro Machado, PhD

Co-Supervisor: José Carlos Ribeiro, PhD

Nelson João da Cunha Azevedo

Porto, 2023

FICHA DE CATALOGAÇÃO

Azevedo, N. (2023). *Back pain: measurements of spine deviations and balance; associated risk factors and preventive approaches in children and adolescents (9 to 19 years old).* Doctoral Thesis in Physiotherapy. Research Center for Physical Activity, Health, and Leisure. Faculty of Sport of the University of Porto.

Keywords: PREVALENCE; BACK PAIN; SPINE; POSTURE; PHYSICAL ACTIVITY; PHYSICAL FITNESS; BALANCE; CHILDREN; ADOLESCENTS.

This thesis was supported by the Porto Biomechanics Laboratory (LABIOMEP) of the Faculty of Sport of the University of Porto (FADE-UP) and the Research Center for Physical Activity, Health and Leisure (CIAFEL) of the Faculty of Sport of the University of Porto (FADE-UP).

Dedications

To my family and friends who have put up with me and supported me to make this work possible.

To my Professors for their patience, wisdom and guidance, without them it would not have been possible.

“Learning isn’t a way of reaching one’s potential but rather a way of developing it.”

Anders Ericsson

ACKNOWLEDGMENTS

This dissertation was only possible thanks to extraordinary people who supported and encouraged me during this coping process.

First and foremost, I would like to thank Prof. Leandro Machado for his wisdom, guidance, and patience during this formative process. His constant availability and critical analysis were essential for the completion of this work. I remain in my eternal admiration for all he has done for me.

To Prof. José Carlos Ribeiro for all the support and guidance that have enriched this work. I owe a great deal to you. An inspiration.

To my colleagues and friends for life that I made through the PhD, Prof. Marina Saraiva and Prof. Joel Marouvo, who with his continuous support and courage made this journey less costly and an incredible scientific and human learning experience.

To Prof. João Paulo Vilas-Boas and Eng. Pedro Fonseca, responsible for LABIOMEP, the opportunity to use the resources of the laboratory, for which I am very grateful.

To my colleagues at the Nelson Azevedo - Terapias Globais Clinic, namely Maria João Silva, Emanuel Matos, Elsa Costa and Ana Morais for their support in data collection, without which this would not have been possible.

A special thanks to the physical education teachers of the Padre Benjamim Salgado School Group, especially Paulo Pereira and Flávio Salgado for their help and guidance! Without you, this work would not have legs to run on.

To all the study participants, my deepest thanks for their willingness and participation.

Finally, I would like to thank especially my family, my wife Maria João for all the support and sacrifice, my daughters Inês and Ariana for the times I was not there, for the moments I could not play with you, for the moments I could not put you to bed, for all the moments I lost in favor of this work. Thank you very much.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER VI

LIST OF APPENDIXES

LIST OF ANNEXES

LIST OF PUBLICATIONS

This Doctoral Thesis is based on the following original studies, which are referred to in the text by their Roman numerals, respectively:

I. Azevedo, N., Ribeiro, J. C., & Machado, L. (2023). Back pain in children and adolescents: A cross-sectional study. *European Spine Journal.* https://doi.org/10.1007/s00586-023-07751-z

II. Azevedo, N., Ribeiro, J. C., & Machado, L. (2022). Balance and Posture in Children and Adolescents: A Cross-Sectional Study. *Sensors (Basel, Switzerland), 22*(13), 4973. https://doi.org/10.3390/s22134973

III. Azevedo, N., Ribeiro, J. C., Machado, L. (2021) Is flexibility associated with body composition? Bioimpedance analysis in children and adolescents. In Belinha, J., Campos, J.C.R., Fonseca, E., Silva, M.H.F., Marques, M.A., Costa, M.F.G, & Oliveira, S. (Eds), Advances and current trends in biomechanics: Proceedings of the 9th Portuguese Congress on Biomechanics, February 19 – 20, 2021, Porto, Portugal (pp. 299-303). Taylor & Francis. https://doi:10.1201/9781003217152-66.

IV. Nelson Azevedo, José Carlos Ribeiro, Leandro Machado. (2023). Back pain, physical activity habits, and physical fitness in children and adolescents. A longitudinal study including Covid-19 lockdown. (Submitted to Journal of Epidemiology and Global Health)

The following abstracts were published:

1. Nelson Azevedo, José Carlos Ribeiro, Leandro Machado. (2021) Is flexibility associated with body composition? Bioimpedance analysis in children and adolescents. 9th Portuguese Congress on Biomechanics (2021)

2. Nelson Azevedo, José Carlos Ribeiro, Leandro Machado. (2023) Trunk body composition and relationship with spinal flexion mobility. 10th Portuguese Congress on Biomechanics (2023)

ABSTRACT

Back pain occurs in all age groups, and although it is more common in the adult population, it is becoming increasingly common in the younger population with varying effects. Nevertheless, the precipitating factors for back pain in the adult and younger populations are still not well understood, and changes in daily habits and lifestyle may contribute to this manifestation of back pain. This knowledge is extremely important for health professionals who deal with this problem on a daily basis, as well as for the general population, in order to develop health promotion and primary prevention strategies. Therefore, the aim of this study was to analyze the different factors influencing back pain in children and adolescents through a cross-sectional study and another one-year longitudinal study. The sample consisted of individuals of both genders aged 9 to 19 years, from the Padre Benjamim Salgado school group between September 2019 and November 2020. Online questionnaires were used as assessment tools to characterize the sample, including characterization of spinal pain. The other assessment tools were the Spinal Mouse® for spinal posture and mobility, the InBody 230® bioimpedance scale for body composition, the Namrol® Podoprint® pressure platform for static balance, and the FITescola® test battery for physical fitness. The results show the high prevalence of back pain in the younger population, as well as the various associated factors such as physical activity or posture, habits related to new technologies such as smartphone use, and, in the longitudinal study, physical fitness.

With this work, we are deepening the understanding of this multifactorial phenomenon that affects children and adolescents, who will be the adults of tomorrow, so that we can all together and in an integrated way develop health promotion strategies with different professionals, be they health professionals, sports professionals, teachers or parents.

KEYWORDS: Prevalence; Back pain; Spine; Posture; Physical activity; Physical fitness; Balance; Children; Adolescents.

RESUMO

A dor de costas é transversal a todas as idades, e apesar de ser mais frequente na população adulta, a população mais jovem apresenta cada vez maior prevalência, com diferentes implicações. No entanto, os fatores desencadeantes da dor de costas na população adulta, e mais jovem, ainda não estão bem estabelecidos, sendo que a alteração de hábitos da vida diária e estilos de vida poderão contribuir para essa manifestação de dor de costas. Esse conhecimento é de estrema importância para os profissionais de saúde que lidam diariamente com esta problemática, mas também para a população geral, de forma a criar estratégias de promoção da saúde e prevenção primária. Assim, o objetivo deste trabalho foi analisar os diferentes fatores que influenciam a dor de costas nas crianças e adolescentes através de um estudo transversal e outro estudo longitudinal com duração de um ano. A amostra foi constituída por indivíduos de ambos os géneros com idades compreendidas entre os 9 e os 19 anos do agrupamento de escolas padre Benjamim Salgado entre setembro de 2019 e novembro de 2020. Um questionário online foi utilizado como instrumento de avaliação para caracterização da amostra, incluindo caracterização da dor vertebral. Os outros instrumentos de avaliação foram o Spinal Mouse® para avaliação da postura e mobilidade da coluna vertebral; a balança de bio impedância Inbody 230® para a composição corporal; a plataforma de pressões Namrol® Podoprint® para o equilíbrio estático; e a bateria de testes FITescola® para a aptidão física. Os resultados evidenciam a alta prevalencia da dor de costas na população mais jovem, assim como os diferentes fatores associados, como a atividade física e a postura, os hábitos associados às novas tecnologias como por exemplo o uso do telemóvel, e no estudo longitudinal a aptidão física. Com este trabalho aprofundamos ainda mais a compreensão deste fenómeno multifatorial que afeta crianças e jovens, que serão os adultos de amanhã, para que possamos todos em conjunto e de forma integrada, elaborar estratégias com os diferentes profissionais, sejam profissionais de saúde, profissionais do exercício, professores ou pais, para a promoção da saúde.

Palavras-chave: Prevalência; Dor de costas; Coluna vertebral; Postura; Atividade fisica; Equilíbrio; Crianças; Adolescentes.

LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS

20m-SR 20 m Shuttle Run

AFP Athletic flexibility profile

BFM Body Fat Mass

BMI Body Mass Index

BMR Basal Metabolic Rate

CoP Center of Pressure

dAP CoP CoP Anterior/Posterior total displacement

dML CoP CoP lateral/medial total displacement

EMG Electromyography

FFM Fat Free Mass

LPF Low flexibility profile

NPF Normal flexibility profile

NRS-11 11-point Numeric Rating Scale

OR Odds Ratio

PBF Percentage Body Fat

SEM standard error of measurement

SM Spinal Mouse

SMM Skeletal Muscle Mass

SR-T Sit-and-Reach Test

v CoP CoP mean velocity of displacement

vAP CoP CoP anterior/posterior mean velocity of displacement

vML CoP CoP lateral/medial mean velocity of displacement

WHR Waist-Hip Ratio

CHAPTER I

GENERAL INTRODUCTION

The decision to study back pain in children and adolescents is related to the need to analyze the factors that influence this phenomenon at an earlier stage of life.

After analysing the scientific literature in the field of back pain in children and adolescents in international and national studies, we believe that it would be important to make a more comprehensive assessment of the current risk factors such as sedentary lifestyle, physical activity, physical fitness, spinal posture, using posture and balance assessment instruments, that could contribute to a deeper understanding of the problem of back pain.

Thus, the need arose to evaluate the prevalence of back pain through a cross-sectional study of the various precipitating factors for the manifestation of back pain **(Chapter III)**. In this study, anthropometric data were analyzed, i.e., age, mass and height, as well as body composition using BMI and PBF. Habits related to physical activity and sedentary lifestyle were also analyzed. Physical fitness was assessed using the FITescola® test battery. The FITescola® data were classified into three groups for each physical fitness parameter according to the program reference values **(Annex A)**. Postural analysis was performed with the Spinal Mouse® in the sagittal and frontal planes, assessing the pelvis, lumbar spine and thoracic spine in the orthostatic position. The results of this study show that half of the participants experienced back pain at least once in their lives (50.6%). The lumbar spine and thoracic spine were most frequently mentioned. The most commonly reported pain intensity was slight pain, followed by moderate pain. Age, female gender, percent body fat, prolonged smartphone and computer use, were factors with a higher relative risk of back pain. Physical activity or sport competitively and video games have a protective effect. Hyperkyphosis and the lateral global spine tilt to the left side increase the risk of back pain.

Already during the first assessment, an analysis of the relationship between body posture and static balance data was performed using stabilometry data **(Chapter IV)**. The evaluation of the body posture was performed with the Spinal Mouse® in the sagittal plane. The stabilometry data was evaluated using the Namrol® Podoprint® pressure platform. The stabilometry parameters evaluated were the

CoP sway path length (Sway path CoP), CoP ellipse area/surface displacement (Area CoP), CoP mean velocity displacement (v CoP), CoP lateral/medial mean velocity displacement (vML CoP), CoP anterior/posterior mean velocity displacement (vAP CoP), CoP lateral/medial total displacement (dML CoP), and CoP Anterior/Posterior total displacement (dAP CoP). The results of this study show that girls had better balance than boys. The anthropometric data showed a weak correlation with the stabilometry data and the postural angles of the studied vertebral regions. When we correlate the postural angles and the stabilometry data, we found that the postural angles were poor predictors of the stabilometry variables. As for back pain, increasing the postural angle of the thoracic spine increases the probability of manifesting back pain by 3%.

Another study related to the first assessment, relating body composition to flexibility, was performed **(Chapter V)**. Flexibility was assessed with FITescola® test battery, and body composition was assessed with Inbody 230®. Individuals were divided into low profile, normal profile, and high flexibility profile groups according to the FITescola® program reference values **(Annex A)**. The results of this study showed differences between genders in flexibility and body composition parameters. Some body composition parameters were associated with flexibility level, namely increased skeletal muscle mass (SMM), basal metabolic rate (BMR), Waist-Hip Ratio (WHR), and age. In females, Body Fat Mass (BFM) was associated with lower levels of flexibility, while Body Mass Index (BMI) and older age were associated with higher levels of flexibility. In males, SMM, Fat Free Mass (FFM), and age are related to increased flexibility.

A cross-sectional study has limitations in terms of causality, so a longitudinal study would be appropriate to understand the influence of various factors on child- and adolescent-reported back pain over time, so a longitudinal study was carried out during one year after the cross-sectional study was evaluated **(Chapter VI)**.

During the longitudinal study's evaluation period, an event shook practically the whole world, with different impacts from country to country. Portugal was no exception, namely the pandemic related to Covid-19, forcing periods of lockdown to contain the pandemic as a public health strategy. This provided the opportunity to study the effects of lockdown on children and adolescents in terms of back pain, physical fitness and physical activity habits. Posture assessment using the Spinal Mouse®, static balance using Namrol® Podoprint® pressure platform, and body composition analysis using the Inbody 230® bioimpedance scale were not possible because it was not allowed for individuals outside the school to enter the school grounds during the pandemic period. Therefore, physical fitness data and a questionnaire characterizing back pain and physical activity habits were collected at the second assessment time point and compared to the data collected at the first assessment time point. The results of this study show that most participants improved their physical fitness, except push-ups in children and female gender and curl-ups in adolescents. During this period, most participants kept doing physical activity regularly. The prevalence of back pain was higher in females compared to males, and the lumbar and thoracic spine had the highest prevalence of back pain. The thoracic spine was most commonly affected in children and the lumbar spine in adolescents. Increasing physical fitness, especially upper body neuromuscular condition through push-ups, had a protective effect on the manifestation of back pain in children and adolescents.

Thus, with this work, we were able to further elaborate on the various factors that influence the manifestation of back pain in children and adolescents, as well as the relationship between posture in the sagittal plane and static balance, the relationship between flexibility and body composition parameters, and the influence of Covid 19 pandemic lockdown.

The General Conclusion and some Considerations as a Professional Physiotherapist finalize the main body of this Thesis.

CHAPTER II

INTRODUCTION

Back pain is a growing problem in today's society, both in the adult population and in the younger population (James et al., 2018; Wu et al., 2020). Because it is a multifactorial condition, there is an increasing need for comprehensive studies to understand the various factors that affect the manifestation of back pain in children and adolescents, due to the direct impact on spinal functionality and in the quality of life in the young population (Balagué et al., 1999; Calvo-Muñoz et al., 2018; Kamper et al., 2016; Watson et al., 2003).

Back pain is not always due to a structural change in the spine or elsewhere (Steffens et al., 2014), especially in the younger population (Harreby et al., 1995), and it is often difficult to find an objective cause for pain in this particular population. Moreover, the consequences of back pain in children and adolescents differ from those in the adult population (Lauridsen et al., 2020), with psychological and social factors playing a more significant role in the pain experience. Furthermore, pain-related anxiety plays an essential role in children's lives, forcing us to think more intensively about the treatment of this clinical condition.

Studies have already been conducted in Portugal that addressed the problem of back pain in children and adolescents, but they used different age groups of children and adolescents and different measurement tools compared to our study (Araújo et al., 2017, 2019; Minghelli et al., 2014; Trigueiro et al., 2013). Those studies are mainly related to posture and do not evaluate balance and physical fitness and their association with back pain in children and adolescents, as we did in our study.

Among the various factors studied that affect the manifestation of back pain, sedentary lifestyle is one of the most important factors, and furthermore, being common to both adults and children, especially nowadays due to the lifestyle of children and adolescents, which is often associated with low levels of physical activity (Kędra et al., 2021; Vierola et al., 2016). These studies showed that very low (and also very high) physical activity is associated with back pain. In a recent systematic review with meta-analysis, a sedentary lifestyle, such as prolonged TV television viewing and computer/cell phone use, was found to be a notable risk factor for low back pain in children and adolescents (Baradaran Mahdavi et al., 2021).

However, there is no consensus in the literature on the protective effect of physical activity in reducing the manifestation of back pain (Franz et al., 2017; Lunde et al., 2015; Skoffer & Foldspang, 2008).

Another important aspect related to back pain is physical fitness, which has been studied recently, but with different results regarding the relationship between physical fitness and the manifestation of back pain (Anza et al., 2013; Bo Andersen et al., 2006; Cardon et al., 2016; Galmés-Panadés & Vidal-Conti, 2022; Henriot-Jéhel et al., 2022). Physical fitness is evaluated in several countries, and in Portugal the physical fitness of children and adolescents is systematically assessed at the beginning and end of each school year in schools using the FITescola® battery test (Henriques-Neto et al., 2020). The test battery includes a series of tests divided into three sections: Aerobic Condition, Body Composition, and Neuromuscular Fitness. Aerobic condition is assessed using the 20-m shuttle run (20m-SR). Body Composition is evaluated by Body Mass Index (BMI). Neuromuscular fitness is assessed in three components: trunk neuromuscular condition by abdominal strength (number of curl-ups), upper body neuromuscular condition by maximum number of push-ups in a series, and lower body neuromuscular condition by long jump. Flexibility is evaluated with the sit and reach test (SR-T).

Body composition is an important factor in various dimensions, and it is also a predictor of the manifestation of back pain in both adults (Baek et al., 2022; Hussain et al., 2017) and children (Cejudo et al., 2020; Minghelli et al., 2015; Silva et al., 2014).

Posture is another factor that seems to play a prominent role in the manifestation of back pain (Minghelli et al., 2014). However, there are different concepts of posture, and the difficulty of defining a concept that encompasses all the dynamics of the human body is a real challenge. According to Magee (2014), posture, is the relative position of the body at any given moment, and therefore, is a composition of the positions of the different joints of the body at that moment (Magee, 2014). There are two types of posture (Levangie & Norkin, 2005): static posture, in which the body and its segments are aligned and remain in certain positions, such as standing, sitting, or lying down; and dynamic posture, in which the body or its segments are in motion, such as walking, running, jumping, etc.

There are several methods for assessing spinal posture (Kim et al., 2022; Michaud et al., 2022; Takatalo et al., 2020; Vogt et al., 2000), with x-ray picture being the "gold standard" assessment system, but the use is limited because of radiation, and its adverse effects on humans, which are becoming increasingly known (Ronckers et al., 2010). The Spinal Mouse® overcomes this limitation and provides reliable information (Barrett et al., 2014; Mannion et al., 2004), both in the adult (Guermazi et al., 2006) and pediatric research (Livanelioglu et al., 2016). The standard error of measurement (SEM) for all reference values is ± 3º, which corresponds to the value determined by Mannion et al. (2004). The Spinal Mouse allows us to perform a faster and lower-risk spine postural assessment than with radiographs, especially in younger age groups.

Cobb angles are the reference angles for spinal assessment, constituting an assessment system that is a reference system in both research and clinical practice (Jin et al., 2022; Schreiber et al., 2019). A recent systematic review (Furlanetto et al., 2018) attempted to understand what are the reference values for Cobb angles in the sagittal plane in different populations, whether children, adolescents, or adults, and identified the cutoff values that served as the reference for this work, namely the reference values for normal posture and its deviations in different regions of the spine.

Each joint's position affects the other joints (Magee, 2014). Therefore, the relationship between the different segments in different postures is crucial for a good postural balance (Pollock et al., 2000), with special attention to the spine. When we speak of postural balance, we must also speak of postural competence, and specifically, postural competence of the spine. Postural competence of the spine can be defined as the balance between the external forces acting on the spine and the muscular response of the trunk, which is sensory regulated to maintain a stable upright posture both statically and dynamically (Lamartina & Berjano, 2014; Zurawski et al., 2020). In this context, the relationship between the spine and the foot is extremely important (Le Huec et al., 2019), and the relationship between the sensory information of the foot and that of the spine is crucial for optimal posture and efficient balance control (Zurawski et al., 2020).

Balance control can be defined as the appropriate response to perturbations of the center of pressure caused by the oscillation of the center of gravity, motor activity, or conscious interaction with the environment (Błaszczyk et al., 2020). Balance involves the coordination of sensorimotor strategies to stabilize the body's center of pressure (CoP) in the presence of both self-initiated and externally-initiated disturbances of stability (Horak, 2006).

Understanding the relationship between posture and balance in children and adolescents is becoming increasingly important today due to lifestyle changes and their interrelationship with spine pathologies (Szita et al., 2018). Analysis of static balance using stabilometry data from pressure platforms has been used to analyze balance in children and adolescents. Studies that also analyze stabilometry data and the association with manifestation of back pain highlight their possible relationship (Menz et al., 2013; O'Leary et al., 2013). The Namrol® Podoprint® pressure platform (Medicapteurs France SAS, Balma, France) has been used to collect plantar pressure and stabilometry data and has been shown to be reliable and reproducible (Cobos-Moreno et al., 2022; Pereiro-Buceta et al., 2021)

The above literature review highlights the need to understand better the phenomenon of back pain in children and adolescents, and for this purpose, it is important to conduct a series of studies to deepen this knowledge. The following chapters address the different studies that we have carried out with this aim, and it is now possible to obtain more objective data on back pain in children and adolescents in Portugal.

REFERENCES

Abelin-Genevois, K. (2021). Sagittal balance of the spine. *Orthopaedics & Traumatology: Surgery & Research, 107*(1), 102769. https://doi.org/10.1016/J.OTSR.2020.102769.

Anza, R., Denis, M., & Silva, M. F. (2013). Analysis of physical fitness, anthropometry and prevalence of musculoskeletal symptoms in the youth volleyball category. *Revista Brasileira de Medicina Do Esporte, 19*(1), 62–65. https://doi.org/10.1590/S1517-86922013000100013.

Araújo, F. A., Severo, M., Alegrete, N., Howe, L. D., & Lucas, R. (2017). Defining Patterns of Sagittal Standing Posture in Girls and Boys of School Age. *Physical Therapy, 97*(2), 258–267. https://doi.org/10.2522/ptj.20150712.

Araújo, F. A., Simões, D., Silva, P., Alegrete, N., & Lucas, R. (2019). Sagittal standing posture and relationships with anthropometrics and body composition during childhood. *Gait and Posture, 73*, 45–51. https://doi.org/10.1016/j.gaitpost.2019.07.130.

Baek, S., Park, H., & Kim, G. (2022). Associations Between Trunk Muscle/Fat Composition, Narrowing Lumbar Disc Space, and Low Back Pain in Middle-Aged

Farmers: A Cross-Sectional Study. *Annals of Rehabilitation Medicine, 46*(3), 122–132. https://doi.org/10.5535/arm.21201.

Balagué, F., Troussier, B., & Salminen, J. J. (1999). Non-specific low back pain in children and adolescents: Risk factors. *European Spine Journal: Official Publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 8*(6), 429–438. https://doi.org/10.1007/s005860050201.

Baradaran Mahdavi, S., Riahi, R., Vahdatpour, B., & Kelishadi, R. (2021). Association between sedentary behavior and low back pain; A systematic review and meta-analysis. *Health Promotion Perspectives, 11*(4), 393–410. https://doi.org/10.34172/hpp.2021.50.

Barrett, E., McCreesh, K., & Lewis, J. (2014). Reliability and validity of non-radiographic methods of thoracic kyphosis measurement: A systematic review. *Manual Therapy, 19*(1), 10–17. https://doi.org/10.1016/J.MATH.2013.09.003.

Birnie, K. A., Hundert, A. S., Lalloo, C., Nguyen, C., & Stinson, J. N. (2019). Recommendations for selection of self-report pain intensity measures in children and adolescents: A systematic review and quality assessment of measurement properties. *Pain, 160*(1), 5–18. https://doi.org/10.1097/j.pain.0000000000001377.

Błaszczyk, J. W., Fredyk, A., Błaszczyk, P. M., & Ashtiani, M. (2020). Step Response of Human Motor System as a Measure of Postural Stability in Children. *IEEE Transactions on Neural Systems and Rehabilitation Engineering : A Publication of the IEEE Engineering in Medicine and Biology Society, 28*(4), 895–903. https://doi.org/10.1109/TNSRE.2020.2974784.

Bo Andersen, L., Wedderkopp, N., & Leboeuf-Yde, C. (2006). Association between back pain and physical fitness in adolescents. *Spine, 31*(15), 1740–1744. https://doi.org/10.1097/01.brs.0000224186.68017.e0.

Calvo-Muñoz, I., Kovacs, F. M., Roqué, M., Fernández, I. G., & Calvo, J. S. (2018). Risk Factors for Low Back Pain in Childhood and Adolescence: A Systematic Review. *Clinical Journal of Pain, 34*(5). https://doi.org/10.1097/AJP.0000000000000558.

Cardon, G., De Bourdeaudhuij, I., De Clercq, D., Philippaerts, R., Verstraete, S., & Geldhof, E. (2016). Physical Fitness, Physical Activity, and Self-Reported Back and

Neck Pain in Elementary Schoolchildren. *Pediatric Exercise Science, 16*(2), 147–157. https://doi.org/10.1123/pes.16.2.147.

Cejudo, A., Ginés-Díaz, A., Rodríguez-Ferrán, O., Santonja-Medina, F., & Sainz de Baranda, P. (2020). Trunk Lateral Flexor Endurance and Body Fat: Predictive Risk Factors for Low Back Pain in Child Equestrian Athletes. *Children, 7*(10), Article 10. https://doi.org/10.3390/children7100172.

Cobos-Moreno, P., Astasio-Picado, Á., Martínez- Nova, A., Sánchez- Rodríguez, R., Escamilla-Martínez, E., & Gómez-Martín, B. (2022). The Podoprint® plantar pressure platform: Evaluation of reliability and repeatability, and determination of the normality parameters. *Journal of Tissue Viability, 31*(4), 619–624. https://doi.org/10.1016/j.jtv.2022.07.005.

Franz, C., Møller, N. C., Korsholm, L., Jespersen, E., Hebert, J. J., & Wedderkopp, N. (2017). Physical activity is prospectively associated with spinal pain in children (CHAMPS Study-DK). *Scientific Reports, 7*(1), 4–11. https://doi.org/10.1038/s41598-017-11762-4.

Furlanetto, T. S., Sedrez, J. A., Candotti, C. T., & Loss, J. F. (2018). Reference values for Cobb angles when evaluating the spine in the sagittal plane: A systematic review with meta-analysis. *Motricidade, 14*(2–3), Article 2–3. https://doi.org/10.6063/motricidade.10890.

Galmés-Panadés, A. M., & Vidal-Conti, J. (2022). Association between Physical Fitness and Low Back Pain: The Pepe Cross-Sectional Study. *Children, 9*(9), Article 9. https://doi.org/10.3390/children9091350.

García-Hermoso, A., Ramírez-Campillo, R., & Izquierdo, M. (2019). Is Muscular Fitness Associated with Future Health Benefits in Children and Adolescents? A Systematic Review and Meta-Analysis of Longitudinal Studies. *Sports Medicine, 49*(7), 1079–1094. https://doi.org/10.1007/S40279-019-01098-6/TABLES/3.

Guermazi, M., Ghroubi, S., Kassis, M., Jaziri, O., Keskes, H., Kessomtini, W., Ben Hammouda, I., & Elleuch, M.-H. (2006). [Validity and reliability of Spinal Mouse to assess lumbar flexion]. *Annales De Readaptation Et De Medecine Physique: Revue Scientifique De La Societe Francaise De Reeducation Fonctionnelle De Readaptation Et De Medecine Physique, 49*(4), 172–177. https://doi.org/10.1016/j.annrmp.2006.03.001.

Harreby, M., Neergaard, K., Hesselsøe, G., & Kjer, J. (1995). Are radiologic changes in the thoracic and lumbar spine of adolescents risk factors for low back pain in adults? A 25-year prospective cohort study of 640 school children. *Spine, 20*(21), 2298–2302. https://doi.org/10.1097/00007632-199511000-00007.

Harreby, M., Neergaard, K., Hesselsøe, G., & Kjer, J. (1995). Are radiologic changes in the thoracic and lumbar spine of adolescents risk factors for low back pain in adults? A 25-year prospective cohort study of 640 school children. *Spine, 20*(21), 2298–2302. https://doi.org/10.1097/00007632-199511000-00007.

Harreby, M., Nygaard, B., Jessen, T., Larsen, E., Storr-Paulsen, A., Lindahl, A., Fisker, I., & Lægaard, E. (1999). Risk factors for low back pain in a cohort of 1389 Danish school children: An epidemiologic study. *European Spine Journal, 8*(6), 444–450. https://doi.org/10.1007/s005860050203.

Henriot-Jéhel, C., Lemire, J., Teulier, C., Bussières, A., & Lardon, A. (2022). Factors associated with back pain in children aged 6 to 12 years of age, an eight months prospective study. *Scientific Reports, 12*(1), Article 1. https://doi.org/10.1038/s41598-021-04060-7.

Henriques-Neto, D., Minderico, C., Peralta, M., Marques, A., & Sardinha, L. B. (2020). Test–retest reliability of physical fitness tests among young athletes: The FITescola® battery. *Clinical Physiology and Functional Imaging, 40*(3), 173–182. https://doi.org/10.1111/CPF.12624.

Horak, F. B. (2006). MECHANISTIC AND PHYSIOLOGICAL ASPECTS Postural orientation and equilibrium: What do we need to know about neural control of balance to prevent falls? *Age and Ageing,* 7–11. https://doi.org/10.1093/ageing/afl077.

Hussain, S. M., Urquhart, D. M., Wang, Y., Shaw, J. E., Magliano, D. J., Wluka, A. E., & Cicuttini, F. M. (2017). Fat mass and fat distribution are associated with low back pain intensity and disability: Results from a cohort study. *Arthritis Research & Therapy, 19*, 26. https://doi.org/10.1186/s13075-017-1242-z.

Imhof, K., Faude, O., Strebel, V., Donath, L., Roth, R., & Zahner, L. (2015). Examining the Association between Physical Fitness, Spinal Flexibility, Spinal Posture and Reported Back Pain in 6 To 8 Year Old Children. *Journal of Novel Physiotherapies 5*(5), 1–7. https://doi.org/10.4172/2165-7025.1000274.

James, S. L., Abate, D., Abate, K. H., Abay, S. M., Abbafati, C., Abbasi, N., Abbastabar, H., Abd-Allah, F., Abdela, J., Abdelalim, A., Abdollahpour, I., Abdulkader, R. S., Abebe, Z., Abera, S. F., Abil, O. Z., Abraha, H. N., Abu-Raddad, L. J., Abu-Rmeileh, N. M. E., Accrombessi, M. M. K., … Murray, C. J. L. (2018). Global, regional, and national incidence, prevalence, and years lived with disability for 354 Diseases and Injuries for 195 countries and territories, 1990-2017: A systematic analysis for the Global Burden of Disease Study 2017. *The Lancet, 392*(10159), 1789–1858. https://doi.org/10.1016/S0140-6736(18)32279-7.

Jin, C., Wang, S., Yang, G., Li, E., & Liang, Z. (2022). A Review of the Methods on Cobb Angle Measurements for Spinal Curvature. *Sensors (Basel, Switzerland), 22*(9), 3258. https://doi.org/10.3390/s22093258.

Kamper, S. J., Yamato, T. P., & Williams, C. M. (2016). The prevalence, risk factors, prognosis and treatment for back pain in children and adolescents: An overview of systematic reviews. *Best Practice & Research Clinical Rheumatology, 30*(6), 1021–1036. https://doi.org/10.1016/J.BERH.2017.04.003.

Kauffman, T. L. (2007). Chapter 15—Posture. In T. L. Kauffman, J. O. Barr, & M. Moran (Eds.), *Geriatric Rehabilitation Manual (Second Edition)* (pp. 99–105). Churchill Livingstone. https://doi.org/10.1016/B978-0-443-10233-2.50022-5.

Kędra, A., Plandowska, M., Kędra, P., & Czaprowski, D. (2021). Physical activity and low back pain in children and adolescents: A systematic review. *European Spine Journal : Official Publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 30*(4), 946–956. https://doi.org/10.1007/S00586-020-06575-5.

Kendall, F. P., & Kendall, F. P. (Eds.). (2005). *Muscles: Testing and function with posture and pain (5th ed)*. Lippincott Williams & Wilkins.

Kim, K. H., Sohn, M.-J., & Park, C. G. (2022). Conformity assessment of a computer vision-based posture analysis system for the screening of postural deformation. *BMC Musculoskeletal Disorders, 23*(1), 799. https://doi.org/10.1186/s12891-022-05742-7.

Lamartina, C., & Berjano, P. (2014). Classification of sagittal imbalance based on spinal alignment and compensatory mechanisms. *European Spine Journal, 23*(6), 1177–1189. https://doi.org/10.1007/s00586-014-3227-9.

Latash, M. L., & Zatsiorsky, V. M. (2016). 14—Posture. In M. L. Latash & V. M. Zatsiorsky (Eds.), *Biomechanics and Motor Control* (pp. 305–333). Academic Press. https://doi.org/10.1016/B978-0-12-800384-8.00014-4.

Lauridsen, H. H., Stolpe, A. B., Myburgh, C., & Hestbæk, L. (2020). What are important consequences in children with non-specific spinal pain? A qualitative study of Danish children aged 9-12 years. *BMJ Open, 10*(10). https://doi.org/10.1136/BMJOPEN-2020-037315.

Le Huec, J. C., Thompson, W., Mohsinaly, Y., Barrey, C., & Faundez, A. (2019). Sagittal balance of the spine. *European Spine Journal: Official Publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 28*(9), 1889–1905. https://doi.org/10.1007/s00586-019-06083-1.

Levangie, P. K., & Norkin, C. C. (2005). *Joint structure and function: A comprehensive analysis (4th ed).* F.A. Davis Co.

Livanelioglu, A., Kaya, F., Nabiyev, V., Demirkiran, G., & Fırat, T. (2016). The validity and reliability of "Spinal Mouse" assessment of spinal curvatures in the frontal plane in pediatric adolescent idiopathic thoraco-lumbar curves. *European Spine Journal, 25*(2), 476–482. https://doi.org/10.1007/s00586-015-3945-7.

Ludwig, O. (2017). Interrelationship between postural balance and body posture in children and adolescents. *Journal of Physical Therapy Science, 29*(7), 1154–1158. https://doi.org/10.1589/JPTS.29.1154.

Ludwig, O., Kelm, J., Hammes, A., Schmitt, E., & Fröhlich, M. (2020). Neuromuscular performance of balance and posture control in childhood and adolescence. *Heliyon, 6*(7). https://doi.org/10.1016/J.HELIYON.2020.E04541.

Lunde, L. K., Koch, M., Hanvold, T. N., Wærsted, M., & Veiersted, K. B. (2015). Low back pain and physical activity—A 6.5 year follow-up among young adults in their transition from school to working life Plant-abiotic interactions. *BMC Public Health, 15*(1). https://doi.org/10.1186/s12889-015-2446-2.

MacDonald, J., Stuart, E., & Rodenberg, R. (2017). Musculoskeletal Low Back Pain in School-aged Children: A Review. *JAMA pediatrics, 171*(3), 280–287. https://doi.org/10.1001/jamapediatrics.2016.3334.

Magee, D. J. (2014). *Orthopedic physical assessment. (Sixth edition).* Elsevier Saunders.

Mannion, A. F., Knecht, K., Balaban, G., Dvorak, J., & Grob, D. (2004). A new skin-surface device for measuring the curvature and global and segmental ranges of motion of the spine: Reliability of measurements and comparison with data reviewed from the literature. *European Spine Journal, 13*(2), 122–136. https://doi.org/10.1007/s00586-003-0618-8.

Menz, H. B., Dufour, A. B., Riskowski, J. L., Hillstrom, H. J., & Hannan, M. T. (2013). Foot posture, foot function and low back pain: The Framingham Foot Study. *Rheumatology (Oxford, England), 52*(12), 2275. https://doi.org/10.1093/RHEUMATOLOGY/KET298.

Menz, H. B., Morris, M. E., & Lord, S. R. (2005). Foot and ankle characteristics associated with impaired balance and functional ability in older people. The Journals of Gerontology. Series A, *Biological Sciences and Medical Sciences, 60*(12), 1546–1552. https://doi.org/10.1093/GERONA/60.12.1546.

Michaud, F., Lugrís, U., & Cuadrado, J. (2022). Determination of the 3D Human Spine Posture from Wearable Inertial Sensors and a Multibody Model of the Spine. *Sensors (Basel, Switzerland), 22*(13), 4796. https://doi.org/10.3390/s22134796.

Minghelli, B., Oliveira, R., & Nunes, C. (2014). Non-specific low back pain in adolescents from the south of Portugal: Prevalence and associated factors. *Journal of Orthopaedic Science, 19*(6), 883–892. https://doi.org/10.1007/s00776-014-0626-z.

Minghelli, B., Oliveira, R., & Nunes, C. (2015). Association of obesity with chronic disease and musculoskeletal factors. *Revista da Associacao Medica Brasileira (1992), 61*(4), 347–354. https://doi.org/10.1590/1806-9282.61.04.347.

O'Leary, C. B., Cahill, C. R., Robinson, A. W., Barnes, M. J., & Hong, J. (2013). A systematic review: The effects of podiatrical deviations on nonspecific chronic low back pain. *Journal of Back and Musculoskeletal Rehabilitation, 26*(2), 117–123. https://doi.org/10.3233/BMR-130367.

Pereiro-Buceta, H., Calvo-Lobo, C., Becerro-De-bengoa-vallejo, R., Losa-Iglesias, M. E., Romero-Morales, C., López-López, D., & Martínez-Jiménez, E. M. (2021). Intra and intersession repeatability and reliability of dynamic parameters in pressure platform assessments on subjects with simulated leg length discrepancy. A cross-sectional research. *Sao Paulo Medical Journal, 139*(5), 424–434. https://doi.org/10.1590/1516-3180.2020.0791.R1.110321.

Pollock, A. S., Durward, B. R., Rowe, P. J., & Paul, J. P. (2000). What is balance? *Clinical Rehabilitation, 14*(4), 402–406. https://doi.org/10.1191/0269215500cr342oa.

Ronckers, C. M., Land, C. E., Miller, J. S., Stovall, M., Lonstein, J. E., & Doody, M. M. (2010). Cancer mortality among women frequently exposed to radiographic examinations for spinal disorders. *Radiation Research, 174*(1), 83–90. https://doi.org/10.1667/RR2022.1.

Ruhe, A., Fejer, R., & Walker, B. (2011). Center of pressure excursion as a measure of balance performance in patients with non-specific low back pain compared to healthy controls: A systematic review of the literature. *European Spine Journal, 20*(3), 358–368. https://doi.org/10.1007/S00586-010-1543-2/TABLES/6.

Schreiber, S., Parent, E. C., Hill, D. L., Hedden, D. M., Moreau, M. J., & Southon, S. C. (2019). Patients with adolescent idiopathic scoliosis perceive positive improvements regardless of change in the Cobb angle—Results from a randomized controlled trial comparing a 6-month Schroth intervention added to standard care and standard care alone. SOSORT 2018 Award winner. *BMC Musculoskeletal Disorders, 20*(1), 319. https://doi.org/10.1186/s12891-019-2695-9.

Shumway-Cook, A., & Woollacott, M. H. (2007). *Motor control: Translating research into clinical practice*. 612.

Silva, M. R. O. G. C. M., Badaró, A. F. V., & Dall'Agnol, M. M. (2014). Low back pain in adolescent and associated factors: A cross sectional study with schoolchildren. *Brazilian Journal of Physical Therapy, 18*(5), 402–409. https://doi.org/10.1590/bjpt-rbf.2014.0051.

Skoffer, B., & Foldspang, A. (2008). Physical activity and low-back pain in schoolchildren. *European Spine Journal, 17*(3), 373–379. https://doi.org/10.1007/s00586-007-0583-8.

Steffens, D., Hancock, M. J., Maher, C. G., Williams, C., Jensen, T. S., & Latimer, J. (2014). Does magnetic resonance imaging predict future low back pain? A systematic review. *European Journal of Pain, 18*(6), 755–765. https://doi.org/10.1002/J.1532-2149.2013.00427.X.

Szita, J., Boja, S., Szilagyi, A., Somhegyi, A., Varga, P. P., & Lazary, A. (2018). Risk factors of non-specific spinal pain in childhood. *European Spine Journal, 27*(5), 1119–1126. https://doi.org/10.1007/s00586-018-5516-1.

Takatalo, J., Ylinen, J., Pienimäki, T., & Häkkinen, A. (2020). Intra- and inter-rater reliability of thoracic spine mobility and posture assessments in subjects with thoracic spine pain. *BMC Musculoskeletal Disorders, 21*(1), 529. https://doi.org/10.1186/s12891-020-03551-4.

Taylor, J. B., Goode, A. P., George, S. Z., & Cook, C. E. (2014). Incidence and risk factors for first-time incident low back pain: A systematic review and meta-analysis. *The Spine Journal : Official Journal of the North American Spine Society, 14*(10), 2299–2319. https://doi.org/10.1016/J.SPINEE.2014.01.026.

Trigueiro, M. J., Massada, L., & Garganta, R. (2013). Back pain in Portuguese schoolchildren: Prevalence and risk factors. *The European Journal of Public Health, 23*(3), 499–503. https://doi.org/10.1093/eurpub/cks105.

Tsze, D. S., Hirschfeld, G., Dayan, P. S., Bulloch, B., & von Baeyer, C. L. (2018). Defining No Pain, Mild, Moderate, and Severe Pain based on the Faces Pain Scale – Revised and Color Analog Scale in Children with Acute Pain. *Pediatric Emergency Care, 34*(8), 537–544. https://doi.org/10.1097/PEC.0000000000000791.

Vierola, A., Suominen, A. L., Lindi, V., Viitasalo, A., Ikävalko, T., Lintu, N., Väistö, J., Kellokoski, J., Närhi, M., & Lakka, T. A. (2016). Associations of Sedentary Behavior, Physical Activity, Cardiorespiratory Fitness, and Body Fat Content With Pain Conditions in Children: The Physical Activity and Nutrition in Children Study. *The Journal of Pain, 17*(7), 845–853. https://doi.org/10.1016/J.JPAIN.2016.03.011.

Vogt, L., Pfeifer, K., Portscher, M., & Banzer, W. (2000). Lumbar corsets: Their effect on three-dimensional kinematics of the pelvis. *Journal of Rehabilitation Research and Development, 37*(5), 495–499.

Watson, K., Papageorgiou, A., Jones, G., Taylor, S., Symmons, D., Silman, A., & Macfarlane, G. (2003). Low back pain in schoolchildren: The role of mechanical and psychosocial factors. *Archives of Disease in Childhood, 88*(1), 12–17. https://doi.org/10.1136/adc.88.1.12.

Wu, A., March, L., Zheng, X., Huang, J., Wang, X., Zhao, J., Blyth, F. M., Smith, E., Buchbinder, R., & Hoy, D. (2020). Global low back pain prevalence and years lived with disability from 1990 to 2017: Estimates from the Global Burden of Disease

Study 2017. *Annals of Translational Medicine, 8*(6), 299–299. https://doi.org/10.21037/ATM.2020.02.175.

Zurawski, A. L., Kiebzak, W. P., Kowalski, I. M., Sliwinski, G., & Sliwinski, Z. (2020). Evaluation of the association between postural control and sagittal curvature of the spine. *PLoS ONE, 15*(10). https://doi.org/10.1371/JOURNAL.PONE.0241228.

CHAPTER III

STUDY I . BACK PAIN IN CHILDREN AND ADOLESCENTS: A CROSS-SECTIONAL STUDY.

Nelson Azevedo[1]*, José Carlos Ribeiro[2] and Leandro Machado[3]

1 CICS, ISAVE, Faculdade de Desporto da Universidade do Porto, 4200-450 Porto, Portugal; nelson.azevedo@docente.isave.pt

2 CIAFEL, ITR, Faculdade de Desporto da Universidade do Porto, 4200-450 Porto, Portugal; jribeiro@fade.up.pt

3 CIFI2D, LABIOMEP, Faculdade de Desporto da Universidade do Porto, 4200-450 Porto, Portugal; lmachado@fade.up.pt

***** *Correspondence: nelson.azevedo@docente.isave.pt*

Current Status: Published on European Spine Journal

Azevedo, N., Ribeiro, J. C., & Machado, L. (2023). Back pain in children and adolescents: A cross-sectional study. European Spine Journal. https://doi.org/10.1007/s00586-023-07751-z.

ABSTRACT

Purpose: Back pain is a growing problem worldwide, not only in adults but also in children. Therefore, it is becoming increasingly important to investigate and understand the factors that influence the early onset of back pain. The aim of this study was to determine the prevalence of back pain in children and adolescents and to identify predisposing risk factors and protective factors.

Methods: A cross-sectional study was conducted between October and December 2019 in schools from northern Portugal, evaluating 1463 students aged 9 to 19 years, of both genders. The instruments used were the Spinal Mouse® to assess posture, the Inbody 230® to assess body composition, an online questionnaire to characterize the sample and back pain, and the FITescola® battery test to access physical fitness.

Results: Half of the subjects experienced back pain at least once in their lifetime. The most frequently mentioned were lumbar spine and thoracic spine, mostly with mild or moderate pain intensities. Age, female gender, percent body fat, prolonged smartphone and computer use, hyperkyphosis, and the lateral global spine tilt to the left side are all factors with higher relative risk of back pain. Practicing physical activity or sports regularly and video games have a protective effect.

Conclusion: The prevalence of back pain in children and adolescents is very high: The study enhances the case for protective factors such as physical activity habits or video games while reinforcing risk factors such as percent body fat, prolonged smartphone or computer use, and posture.

Key words: Back Pain, Children, Adolescents, Prevalence, Risk Factors, Physical Activity.

INTRODUCTION

Back pain is a clinical condition that affects a wide spectrum of the world's population and has implications for public health, as well as economic and social concerns (James et al., 2018). There are several factors associated with the development of back pain, including repetitive activities or a sedentary lifestyle (JB et al., 2014). Symptoms do not always reflect structural changes in the spine (Steffens et al., 2014), and it is important to find the cause of symptoms as early as possible (M et al., 1995). Recent studies focused on how early in human life back pain sets in and how common it is (J et al., 2017; Lauridsen et al., 2020).

Back pain in children and adolescents is a clinical condition that in recent years has seen increased attention from parents and the appropriate medical support services because of its early onset (Lauridsen et al., 2020) but also due to a better understanding of the risk factors (Calvo-Muñoz et al., 2018b). To better characterize this condition, several studies have been conducted recently in several countries, including Portugal (Minghelli et al., 2014; Trigueiro et al., 2013b).

The prevalence of back pain is high among young students (J et al., 2017), with a higher representation of female children (Harreby et al., 1999), but the precipitating factors have not been fully elucidated. A recent meta-analysis studied the relationship between physical fitness and back pain, but the results were inconclusive (García-Hermoso et al., 2019).

This study aims to characterize the prevalence of back pain in children and adolescents from Portugal and the possible protective and risk factors associated with this clinical condition.

MATERIAL AND METHODS

Study design and participants.

A cross-sectional study was carried out with children from a school cluster in northern Portugal (Figure 1), between October and December 2019.

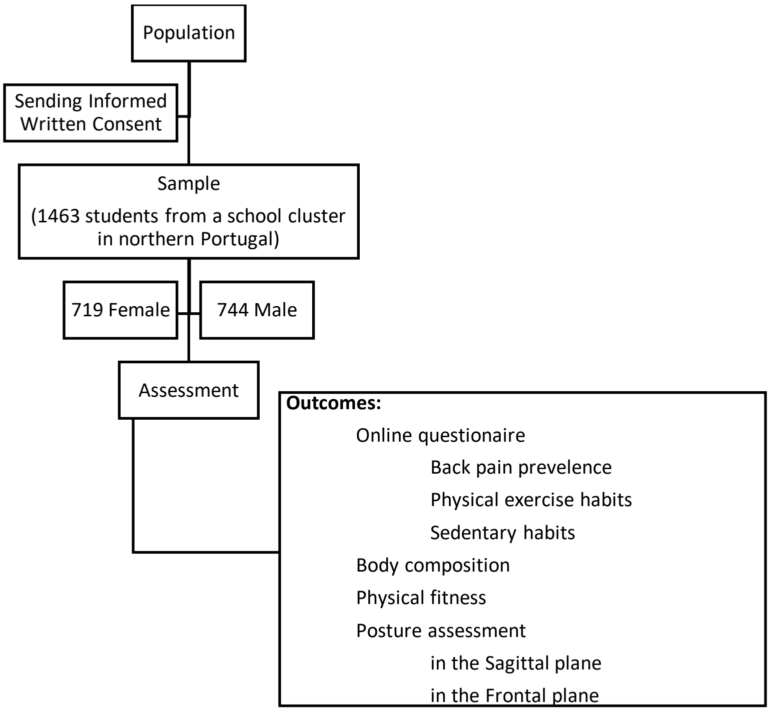

Figure 3.1. Study diagram.

The study was explained to the physical education teachers at the school cluster. Subsequently, a description of the study was given to all students in these schools, and written informed consent was obtained from their parents or guardians after attending a presentation of the project, during which all doubts were resolved. All participants were given the opportunity to decline participation.

Exclusion criteria included students with acute musculoskeletal injuries or serious medical problems that prevented data collection.

This study was conducted according to the guidelines of the Declaration of Helsinki, and all procedures involving human participants were approved by the Ethics Committee of FADEUP—University of Porto (CEFADE 50, 2019). The directors of the participating schools gave their ethical approval and written consent.

The elaboration of the manuscript was based on the STROBE statement guidelines.

Instruments.

An online questionnaire (Google Forms) was used to characterize the sample in terms of anthropometric data, physical activity and sedentary habits, as well as presence of back pain, its prevalence, and location (more than a region could be indicated). Back pain intensity was quantified by an 11-point numeric rating scale

(NRS-11), associated with Faces Pain Scale—Revised (Birnie et al., 2019). Pain classification was based on the study by Tsze et al. (Tsze et al., 2018).

Physical fitness was analyzed using the FITescola® test protocol (Henriques-Neto et al., 2020), where the tests are divided into three sections: Aerobic Condition, evaluated by the 20 m shuttle run; Body Composition, evaluated by Body Mass Index (BMI); and Neuromuscular Fitness assessed in three components: trunk neuromuscular condition through abdominal strength (number of curl-ups), upper body neuromuscular condition through the maximal number of push-ups in one series, and lower body neuromuscular condition through the long jump. Flexibility was assessed with the sit and reach test. The test results were divided into three categories according to the reference values, namely low profile, normal profile, and high profile (Henriques-Neto et al., 2020).

Body Mass Index (BMI) and Percentage Body Fat (PBF) composition were assessed using the InBody 230 (InBody, Cerritos, California, USA) scoring system (D. et al., 2013), a body analysis system based on the bioimpedance of the body. BMI and PBF were divided into three categories, low, normal, and high, adjusted for age and gender (de Onis et al., 2007; McCarthy et al., 2006).

Posture was assessed through spinal evaluation performed using the Spinal Mouse® (Idiag, Voletswil, Switzerland), with proprietary software IDIAG M360pro® version 7.6. Spinal Mouse (SM) is a computerized wireless telemetry device, consisting of 2 wheels, sensors and controllers in a protective casing, acquiring at 150Hz, that is manually guided on the skin along the spine, from the 7th cervical vertebrae to the sacrum to quantify posture and spine mobility (Mannion et al., 2004).

Spinal measurements were performed with the students in the orthostatic reference position and with minimal clothing on the trunk (the girls used tape to hold their bras, always accompanied by the researcher and a female teacher; the boys had their torsos unclothed). Postural analysis in the orthostatic position was performed in the sagittal and frontal planes. In the sagittal plane, posture was considered in four regions, each divided into 3 categories: Thoracic spine: hypokyphosis/neutral/hyperkyphosis; Lumbar spine: hypolordosis/neutral/hyperlordosis; Pelvic tilt: anterior/neutral/posterior; Global spinal sagittal tilt: anterior/neutral/posterior. In the frontal plane, posture was also divided into three categories for the different regions studied: Right/Neutral/Left tilt. The reference angles for spinal curvatures in the sagittal plane in children are:

thoracic kyphosis (33.3° ± 5.4°) and lumbar lordosis L1-L5 (39.6° ± 5.6°); and in adolescents: thoracic kyphosis (35.4° ± 4.9°) and lumbar lordosis L1-L5 (42.7° ± 4.5°) (Furlanetto et al., 2018). The reference values for pelvic tilt in children and adolescents are 7.7° ± 11.3° (Mac-Thiong et al., 2011). In the frontal plane, and global spine in the sagittal plane, the reference values for neutral are 0º(±3º). All the reference values were adjusted by ±3º according to the value of the SM Standard Error of Measurement (SEM) determined by Mannion et al. (Mannion et al., 2004).

The privacy of the students was maintained by providing a private room for the examination. The average duration of each examination was approximately 5 minutes per participant.

Statistical analysis.

Descriptive statistics were used to characterize the sample. Normality of the data was tested by the Kolmogorov-Smirnov test, and most of the variables did not have a normal distribution. Mann–Whitney U-test was used to estimate differences in the studied variables between the two gender groups. The chi-square test was used to estimate the differences between genders and back pain manifestation, as well as the NRS-11 intensity categories and their association with the back regions.

The Phi correlation coefficient test was used to measure the relationship between two binary variables (yes/no; female/male).

For the association between the manifestation of back pain and the variables studied, binary logistic regression was used to calculate the odds ratio (OR). We assumed as a missing value the answer option (I don't know the answer, it depends on the day/week) for those variables including it, because it did not allows to determine a specific answer. Statistical significance was set at $\alpha=0.05$. SPSS version 26 (IBM Inc., Chicago, IL, USA) was used for the statistical computations.

RESULTS

From all school' students, aged 9 to 19 years, whose caretakers freely signed the informed written consent, 1463 agreed to participate in the study (719 female –

49.1%; 744 males – 50.9%).

Through descriptive analysis of the data (Table 3.1), we can observe that there are significant differences between genders in Mass, Height, BMI, PBF and NRS-11, but not in age. The largest significant difference relates to PBF, and the smallest to pain intensity.

Table 3.1. Sample characterization by gender and its association with continuous variables.

	Female	**Male**	**p-value***
	Mean/ SD	Mean/ SD	
Age (yr)	13.98/ 2.43	13.88/ 2.37	0.386
Mass (kg)	54.85/ 13.68	57.17/ 15.46	**0.001**
Height (cm)	157.62/ 8.98	164.03/ 13.97	**0.000**
BMI (kg/m^2)	21.89/ 4.22	20.93/ 3.64	**<0.001**
PBF (%)	29.32/ 8.06	18.38/ 8.77	**0.000**
NRS-11	5.07/ 2.01	4.61/ 1.91	**0.004**

* Mann–Whitney U-test: (level of significance 95%)

Back pain was present in half the children and adolescents, at least once in their lifetime (Table 3.2), with higher prevalence for females (57%). Most back pain complains mentioned occurred in the previous month for both genders, with a higher proportion of those occurring only once (30.1%). Females had a slightly higher percentage of limitations originating from back pain complains than males. The regions with the highest pain prevalence were the lumbar region, followed by the thoracic and cervical spine, and the combination of thoracic + lumbar spine, in both genders.

Table 3.2 Gender differences in the manifestations of back pain.

		Female		Male		Total (F+M)		p-value
		N	%	N	%	N	%	(F/M)
Presence of back pain anytime in the past								
	Yes	410	57.0	330	44.4	740	50.6	**<0.001***
	No	309	43.0	414	55.6	723	49.4	
Total		719	100.0	744	100.0	1463	100.0	
If 'Yes', how long have you had back pain?								
	From 1 day to 1 month	214	52.2	159	48.2	373	50.4	
	From 1 to 3 months	78	19.0	52	15.8	130	17.6	
	From 4 to 6 months	34	8.3	35	10.6	69	9.3	
	From 7 to 9 months	17	4.1	13	3.9	30	4.1	
	From 10 to 12 months	22	5.4	19	5.8	41	5.5	0.475**
	From 13 to 18 months	12	2.9	12	3.6	24	3.2	
	From 19 to 24 months	7	1.7	8	2.4	15	2.0	
	From 25 to 30 months	6	1.5	12	3.6	18	2.4	
	31 months or more	20	4.9	20	6.1	40	5.4	
Total		410	100.0	330	100.0	740	100.0	
How often did back pain occur?								
	Just one time	102	24.9	121	36.7	223	30.1	
	Once per month	46	11.2	41	12.4	87	11.8	
	Once a week	58	14.1	46	13.9	104	14.1	
	2 to 3 times a week	41	10.0	19	5.8	60	8.1	
	4 times or more per week	39	9.5	30	9.1	69	9.3	**0.004****
	I don't know how to answer.	124	30.2	73	22.1	197	26.6	
Total		410	100.0	330	100.0	740	100.0	
This back pain prevents or prevented you from activities from your normal life?								
	Yes	98	23.9	56	17.0	154	20.8	
	No	268	65.4	257	77.9	525	70.9	**<0.001****
	Didn't know	44	10.7	17	5.2	61	8.2	
Total		410	100.0	330	100.0	740	100.0	
What is/was the region of your back pain?								
	C alone	53	12.9	16	4.8	69	9.3	
	T alone	102	24.9	99	30.0	201	27.2	
	L alone	178	43.4	163	49.4	341	46.1	
	P alone	6	1.5	7	2.1	13	1.8	
	C+T	13	3.2	10	3.0	23	3.1	
	T+L	21	5.1	21	6.4	42	5.7	**<0.001****
	L+P	2	0.5	3	0.9	5	0.7	
	C+L	20	4.9	1	0.3	21	2.8	
	C+T+L	10	2.4	7	2.1	17	2.3	
	C+T+L+P	3	0.7	2	0.6	5	0.7	
	T+L+P	2	0.5	0	0.0	2	0.3	
	T+P	0	0.0	1	0.3	1	0.1	

Total	410	100.0	330	100.0	740	100.0	

(Cervical: C; Thoracic: T; Lumbar: L; Pelvic: P)

* Phi correlation coefficient test: (level of significance 95%)

**Chi-Squared Test: (level of significance 95%)

Analysis of the data in Table 3.3 shows that slight pain is the most prevalent (48.2%), followed by moderate pain.

Table 3.3. Number and percentage of subjects accordingly to NRS-11 pain intensity categories and their association with the back regions.

NRS-11 Intensity Categories	No pain (0-2)		Slight pain (3-5)		Moderate pain (6-7)		Intense pain (8-10)		Total NRS-11		p-value*
	N	%	N	%	N	%	N	%	N	%	
C alone	10	10.2	39	10.9	17	7.9	3	4.2	69	9.3	
T alone	37	37.8	100	28.0	52	24.3	12	16.9	201	27.2	
L alone	40	40.8	169	47.3	99	46.3	33	46.5	341	46.1	
P alone	3	3.1	2	0.6	5	2.3	3	4.2	13	1.8	
C+T	3	3.1	9	2.5	8	3.7	3	4.2	23	3.1	
T+L	3	3.1	17	4.8	13	6.1	9	12.7	42	5.7	**<0.001**
L+P	0	0.0	1	0.3	3	1.4	1	1.4	5	0.7	
C+L	1	1.0	11	3.1	8	3.7	1	1.4	21	2.8	
C+T+L	0	0.0	7	2.0	6	2.8	4	5.6	17	2.3	
C+T+L+P	1	1.0	0	0.0	3	1.4	1	1.4	5	0.7	
T+L+P	0	0.0	1	0.3	0	0.0	1	1.4	2	0.3	
T+P	0	0.0	1	0.3	0	0.0	0	0.0	1	0.1	
Total across spine regions	98	100	357	100	214	100	71	100	740	100	
%	13.2		48.2		28.9		9.7		100.0		

(Cervical: C; Thoracic: T; Lumbar: L; Pelvic: P)

*Chi-Squared Test: (level of significance 95%)

When analyzing the odds ratio associated with the development of back pain through binary logistic regression (Table 3.4), we found that females have a 71% higher risk compared to males (OR: 1.71). The risk of developing back pain also increases strongly with age and with PBF.

Competitively performing physical exercise reduces the probability of having back pain by 36% (OR: 0.637) compared to this practice noncompetitively. However, for those performing physical exercise competitively or not, performing 2-3 hours per day of physical exercise increases the risk by 58% (OR:1.579) compared to performing 0-1 hours per day. Analysis of days and hours spent in physical activity, separated between competitive and noncompetitive, is present in Table 3.5.

The use of smartphone or computer shows an increased risk of presenting back pain compared to not using them. A surprising finding is the use of video games for 2 to 3 hours per day that significantly reduces the risk of developing back pain by 50% (OR: 0.50), although based in a small number of students (56 in 1463).

In the analysis of posture, in the sagittal plane, hyperkyphosis showed a 44% (OR: 1.437) increased risk for the manifestation of back pain. In the frontal plane, the lateral spine tilt (left side), is associated with an increased risk of developing back pain (OR: 2.257), although only 52 students showing this lateral tilt.

Table 3.4. Binary logistic regression for the variable back pain and its relationship with the studied variables.

	N	Odds Ratio	95% CI		p-value*
			Lower Bound	Upper Bound	
Gender (*Reference: Male*)	744				
Female	719	**1.708**	1.382	2.111	**<0.001**
Age (*Reference: Under 12 years old*)	307				
Between 12 and 17 years old	1118	**2.842**	2.152	3.705	**<0.001**
Over 17 years old	38	**5.475**	2.593	11.558	**<0.001**
Body composition					
BMI (*Reference: Normal BMI*)	971				
Low BMI	42	0.958	0.510	1.802	0.895
High BMI	450	0.798	0.608	1.046	0.102
PBF (*Reference: Normal PBF*)	659				
Low PBF	207	0.926	0.673	1.273	0.635
High PBF	597	**1.402**	1.078	1.824	**0.012**
Physical exercise habits					
Do you practice physical activity or sport regularly (*Reference: No*)	568				
Yes	895	0.844	0.684	1.042	0.115
Practice physical activity or sport competitively (*Reference: No*)	316				
Yes	579	**0.637**	0.467	0.869	**0.004**
How many days do you practice this physical activity or sport per week (*Reference: 1 to 2 days*)	318				
3-4 days a week	453	1.060	0.773	1.454	0.716

5 or more per week	83	1.317	0.782	2.218	0.301
I don’t know how to answer.	41	1.418	0.707	2.844	0.325
How many hours do you practice this physical activity or sport per day (*Reference: 0 to 1 hour*)	352				
2-3 hours a day	426	**1.579**	1.157	2.153	**0.004**
4 to 5 hours a day	11	1.416	0.413	4.858	0.580
I don’t know how to answer.	106	1.358	0.860	2.143	0.189
Sedentary habits					
How many hours a day do you sit using the computer (*Reference: I don't use computer*)	428				
0 to 1 hour a day	216	**1.427**	1.008	2.019	**0.045**
2-3 hours a day	83	**1.905**	1.135	3.197	**0.015**
4-5 hours a day	31	2.240	0.950	5.280	0.065
6 or more per day	381	1.181	0.882	1.582	0.265
I don’t know how to answer.	324	0.874	0.645	1.184	0.384
How many hours a day to use the mobile phone (*Reference: I don't use mobile phone*)	187				
0 to 1 hour a day	473	**2.066**	1.436	2.974	**<0.001**
2-3 hours a day	320	**3.198**	2.162	4.730	**<0.001**
4-5 hours a day	128	**3.843**	2.365	6.246	**<0.001**
6-7 hours a day	106	**4.070**	2.428	6.825	**<0.001**
More than 8 hour a day	192	**2.401**	1.564	3.684	**<0.001**
I don’t know how to answer.	57	1.340	0.707	2.538	0.369
How many hours a day do you play Video Games (*Reference: I don't play Video Games*)	189				
0 to 1 hour a day	133	0.816	0.511	1.302	0.394
2-3 hours a day	56	**0.501**	0.262	0.959	**0.037**
4-5 hours a day	17	0.535	0.185	1.551	0.250
6-7 hours a day	16	0.489	0.156	1.532	0.219
More than 8 hour a day	232	0.952	0.633	1.433	0.814
I don’t know how to answer.	820	**1.508**	1.081	2.104	**0.016**
Physical fitness					
Aerobic capacity (20-meter shuttle run) (*Reference: Normal profile*)	701				
Low profile	361	1.278	0.976	1.675	0.075
High profile	283	0.917	0.685	1.227	0.560
Abdominal strength (curl-up) (*Reference: Normal profile*)	845				
Low profile	229	0.763	0.559	1.042	0.089
High profile	271	0.996	0.749	1.324	0.976
Upper body muscular fitness (push-up) (*Reference: Normal profile*)	583				
Low profile	534	0.858	0.670	1.099	0.226
High profile	228	0.760	0.554	1.043	0.089
Lower-body muscular fitness (long jump) (*Reference: Normal profile*)	958				
Low profile	322	1.017	0.774	1.336	0.906
High profile	65	1.228	0.733	2.059	0.435

Flexibility (sit and reach) (*Reference: Normal profile*)	465				
Low profile	669	1.033	0.810	1.316	0.795
High profile	211	1.212	0.870	1.688	0.256
Posture - Sagittal plane					
Pelvic tilt *(Reference: Neutral)*	883				
Posterior tilt					
Anterior tilt	580	1.204	0.938	1.545	0.146
Lumbar posture (*Reference: Normal lordosis*)	290				
Hypolordosis	1120	0.981	0.725	1.326	0.899
Hyperlordosis	53	1.266	0.693	2.312	0.442
Thoracic posture (*Reference: Normal kyphosis*)	289				
Hypokyphosis	56	1.124	0.632	1.999	0.691
Hyperkyphosis	1118	**1.437**	1.103	1.872	**0.007**
Global Spine tilt *(Reference – Neutral)*	624				
Posterior tilt	8	1.713	0.401	7.310	0.467
Anterior tilt	831	1.048	0.842	1.304	0.673
Posture - Frontal plane					
Lateral pelvic tilt (*Reference: Neutral*)	1025				
Left side tilt	83	0.699	0.389	1.255	0.231
Right side tilt	355	1.151	0.881	1.503	0.303
Lateral lumbar tilt (*Reference: Neutral*)	631				
Left side tilt	713	1.226	0.952	1.577	0.114
Right side tilt	119	1.691	0.944	3.030	0.077
Lateral thoracic tilt (*Reference: Neutral*)	798				
Left side tilt	126	1.079	0.677	1.720	0.750
Right side tilt	539	0.955	0.755	1.208	0.698
Lateral global spine tilt (*Reference: Neutral*)	1397				
Left side tilt	52	**2.257**	1.234	4.127	**0.008**
Right side tilt	14	0.668	0.226	1.972	0.465

* Binary logistic regression: (level of significance 95%).

Table 3.5 shows that most participants who performed competitive physical activity did so 2-3 hours/day and 3-4 days/week, while those performing it noncompetitively spend 0-1 hours/day and 1-2 days/week.

Table 3.5. Detail of the entry for “Physical exercise habits” presented in Table 3.4.

	hours of physical activity or sport practice per day				
	0 to 1 hour	2-3 hours	4 to 5 hours	I don’t know how to answer	Total
	N	N	N	N	N
Competitive physical activity					
days of physical activity or sport practice per week					
1-2 days	78	55	0	11	144
3-4 days	95	220	3	42	360
5 or more	4	55	3	6	68
I don’t know how to answer.	0	5	0	2	7
Total	177	335	6	61	579
Noncompetitive physical activity					
days of physical activity or sport practice per week					
1-2 days	113	44	0	17	174
3-4 days	47	34	3	9	93
5 or more	4	9	1	1	15
I don’t know how to answer.	11	4	1	18	34
Total	175	91	5	45	316

DISCUSSION

The aim of this study was to investigate back pain in children and adolescents and factors that influence it.

In Portugal, some studies have been conducted, especially by Minghelly et al. (Minghelli et al., 2014), presenting disturbing data on the high prevalence of low back pain in adolescents (62.1% have had low back pain at least once in their lives). Our study shows that half of the students experienced back pain at least once in their lifetime (50.6%), and half of these students reported having had at least one episode of back pain in the previous month. Of the students who reported having back pain, 20.8% had a functional limitation related to that pain.

We considered different regions of the spine to better characterize back pain. The lumbar spine was the most commonly cited, accounting for nearly half of the complaints, followed by the thoracic spine, the cervical spine, and finally the pelvis, which is consistent with other studies (Calvo-Muñoz et al., 2018; J et al., 2017). In our data the greatest difference between genders was found in the cervical spine, with females representing 77% (53/69) of the total students complaining about this region. The most common pain intensities were “Slight pain" and "Moderate pain", with the female gender having a slightly higher mean score in NRS-11 (5.07 vs 4.61).

Analyzing the influence of gender, females showed a higher prevalence of back pain and a higher risk of developing it than males. Age is another significant factor in the manifestation of back pain, especially by comparing the older adolescents to younger children. These two results are consistent with a systematic review by Calvo-Muñoz et al. (Calvo-Muñoz et al., 2018).

Body mass index showed no significant association with the risk of manifestation of back pain. However, our data suggest that children and adolescents with higher PBF have a 40% higher risk of developing back pain than those with normal PBF. These findings are consistent with studies showing the influence of excess body fat on the manifestation of musculoskeletal pain in children and adolescents (Smith et al., 2013). Furthermore, a recent review found an association between increased body fat and lower levels of moderate to vigorous physical activity (Barros et al., 2021).

The association between posture and back pain has been highlighted in some studies (Harreby et al., 1999; Minghelli et al., 2014), particularly in children. Minghelly et al. (Minghelli et al., 2014) found a relationship between posture (assessed with a scoliometer) and the occurrence of low back pain, especially when sitting in poor posture. In our study, a greater association with the manifestation of back pain showed only in the thoracic hyperkyphosis and the lateral global spine tilt (left side). We also see a large number of students with abnormal postures in the sagittal plane, such as anterior tilt of the spine and pelvis and hypolordosis, and in the frontal plane, right tilt of the pelvis and thoracic spine and left tilt of the lumbar spine. Although they are not significant risk factors for back pain, they may have an impact on adult life, and the consequences are often underestimated. These changes were also observed in other studies (Ludwig et al., 2016). Are we seeing the onset of a health problem of future generations? Considering the results for the sagittal and frontal planes, more studies are needed to clarify this question.

We did not find any association between physical fitness (assessed by the FITescola tests) and pain, a result in disagreement with a recent systematic review that found moderate evidence for this association (Kędra et al., 2021).

Sports and physical activity in general acted as protective factors for the development of back pain. However, physical activity for 2-3 hours/day increased the risk of developing back pain compared with 0-1 hour/day. This increase in risk is related to the growth in the number of hours of physical activity, also present at over 4 hours/day, although not significant statistically. These data suggest that practice of sport or physical activity for more than 1 hour consecutively may increase the likelihood of developing back pain in children and adolescents. Sedentary habits are also associated with back pain (Minghelli et al., 2014), and in our case the link with new technologies is particularly emphasized. The use of computers, but especially of smartphones by students, shows a higher risk for the manifestation of back pain. Smartphone use of 4 to 7 hours per day increases the risk of developing back pain by 4 times. These results contrast with a study in which smartphone or computer use did not increase the likelihood of developing back pain (Shan et al., 2013).

Limitations

This study has natural limitations that are characteristic of cross-sectional studies when trying to understand a complex and multifactorial phenomenon. Thus, although we can establish associations between factors, we cannot establish direct causality between them. Although the study has a large sample the fact that it was conducted in a limited geographical area is also a limitation.

For younger children, the limited understanding of the questionnaires and questions was overcome with the help of parents and teachers who kindly helped in a fundamental way in this process.

CONCLUSION

The prevalence of back pain is very high in children and adolescents, with some factors such as higher age, female gender, and sedentary habits contributing negatively to this phenomenon. The posture of the thoracic spine, namely hyperkyphosis, and the lateral global spine tilt (left side) are also important factors in back pain prevalence. There are also protective factors such as sports and physical exercise practice and video games.

REFERENCES

Barros, W. M. A., da Silva, K. G., Silva, R. K. P., Souza, A. P. D. S., da Silva, A. B. J., Silva, M. R. M., Fernandes, M. S. S., de Souza, S. L., & Souza, V. O. N. (2022). Effects of Overweight/Obesity on Motor Performance in Children: A Systematic Review. *Frontiers in endocrinology, 12,* 759165. https://doi.org/10.3389/fendo.2021.759165.

Birnie, K. A., Hundert, A. S., Lalloo, C., Nguyen, C., & Stinson, J. N. (2019). Recommendations for selection of self-report pain intensity measures in children and adolescents: A systematic review and quality assessment of measurement properties. *Pain, 160*(1), 5–18. https://doi.org/10.1097/j.pain.0000000000001377.

Calvo-Muñoz, I., Kovacs, F. M., Roqué, M., Fernández, I. G., & Calvo, J. S. (2018). Risk Factors for Low Back Pain in Childhood and Adolescence: A Systematic Review. *Clinical Journal of Pain, 34*(5), 468–484. https://doi.org/10.1097/AJP.0000000000000558.

de Onis, M., Onyango, A. W., Borghi, E., Siyam, A., Nishida, C., & Siekmann, J. (2007). Development of a WHO growth reference for school-aged children and adolescents. *Bulletin of the World Health Organization, 85*(9), 660–667. https://doi.org/10.2471/blt.07.043497.

Furlanetto, T. S., Sedrez, J. A., Candotti, C. T., & Loss, J. F. (2018). Reference values for Cobb angles when evaluating the spine in the sagittal plane: A systematic review with meta-analysis. *Motricidade, 14*(2–3), Article 2–3. https://doi.org/10.6063/motricidade.10890.

García-Hermoso, A., Ramírez-Campillo, R., & Izquierdo, M. (2019). Is Muscular Fitness Associated with Future Health Benefits in Children and Adolescents? A Systematic Review and Meta-Analysis of Longitudinal Studies. *Sports Medicine, 49*(7), 1079–1094. https://doi.org/10.1007/S40279-019-01098-6/TABLES/3.

Harreby, M., Neergaard, K., Hesselsøe, G., & Kjer, J. (1995). Are radiologic changes in the thoracic and lumbar spine of adolescents risk factors for low back pain in adults? A 25-year prospective cohort study of 640 school children. *Spine, 20*(21), 2298–2302. https://doi.org/10.1097/00007632-199511000-00007.

Harreby, M., Nygaard, B., Jessen, T., Larsen, E., Storr-Paulsen, A., Lindahl, A., Fisker, I., & Lægaard, E. (1999). Risk factors for low back pain in a cohort of 1389 Danish school children: An epidemiologic study. *European Spine Journal, 8*(6), 444–450. https://doi.org/10.1007/s005860050203.

Henriques-Neto, D., Minderico, C., Peralta, M., Marques, A., & Sardinha, L. B. (2020). Test–retest reliability of physical fitness tests among young athletes: The FITescola® battery. *Clinical Physiology and Functional Imaging, 40*(3), 173–182. https://doi.org/10.1111/CPF.12624.

James, S. L., Abate, D., Abate, K. H., Abay, S. M., Abbafati, C., Abbasi, N., Abbastabar, H., Abd-Allah, F., Abdela, J., Abdelalim, A., Abdollahpour, I., Abdulkader, R. S., Abebe, Z., Abera, S. F., Abil, O. Z., Abraha, H. N., Abu-Raddad, L. J., Abu-Rmeileh, N. M. E., Accrombessi, M. M. K., … Murray, C. J. L. (2018). Global, regional, and national incidence, prevalence, and years lived with disability for 354 Diseases and Injuries for 195 countries and territories, 1990-2017: A systematic analysis for the Global Burden of Disease Study 2017. *The Lancet, 392*(10159), 1789–1858. https://doi.org/10.1016/S0140-6736(18)32279-7.

Karelis, D., Chamberland, G., Aubertin-Leheudre, M., Duval, C., & Ecological Mobility in Aging and Parkinson (EMAP) group. (2013). Validation of a portable bioelectrical impedance analyzer for the assessment of body composition. *Applied Physiology, Nutrition, and Metabolism, 38(*1), 27-32. https://doi.org/10.1139/apnm-2012-0129.

Kędra, A., Plandowska, M., Kędra, P., & Czaprowski, D. (2021). Physical activity and low back pain in children and adolescents: A systematic review. European *Spine Journal : Official Publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 30*(4), 946–956. https://doi.org/10.1007/S00586-020-06575-5.

Lauridsen, H. H., Stolpe, A. B., Myburgh, C., & Hestbæk, L. (2020). What are important consequences in children with non-specific spinal pain? A qualitative study of Danish children aged 9-12 years. *BMJ Open, 10*(10). https://doi.org/10.1136/BMJOPEN-2020-037315.

Ludwig, O., Mazet, C., Mazet, D., Hammes, A., & Schmitt, E. (2016). Age-dependency of posture parameters in children and adolescents. *Journal of Physical Therapy Science, 28*(5), 1607–1610. https://doi.org/10.1589/jpts.28.1607.

Mac-Thiong, J. M., Labelle, H., & Roussouly, P. (2011). Pediatric sagittal alignment. *European Spine Journal : Official Publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 20*(5), 586–590. https://doi.org/10.1007/S00586-011-1925-0.

MacDonald, J., Stuart, E., & Rodenberg, R. (2017). Musculoskeletal Low Back Pain in School-aged Children: A Review. *JAMA pediatrics, 171*(3), 280–287. https://doi.org/10.1001/jamapediatrics.2016.3334.

Mannion, A. F., Knecht, K., Balaban, G., Dvorak, J., & Grob, D. (2004). A new skin-surface device for measuring the curvature and global and segmental ranges of motion of the spine: Reliability of measurements and comparison with data reviewed from the literature. *European Spine Journal, 13*(2), 122–136. https://doi.org/10.1007/s00586-003-0618-8.

McCarthy, H. D., Cole, T. J., Fry, T., Jebb, S. A., & Prentice, A. M. (2006). Body fat reference curves for children. *International Journal of Obesity 30*(4), 598–602. https://doi.org/10.1038/sj.ijo.0803232.

Minghelli, B., Oliveira, R., & Nunes, C. (2014). Non-specific low back pain in adolescents from the south of Portugal: Prevalence and associated factors. *Journal of Orthopaedic Science, 19*(6), 883–892. https://doi.org/10.1007/s00776-014-0626-z.

Shan, Z., Deng, G., Li, J., Li, Y., Zhang, Y., & Zhao, Q. (2013). Correlational Analysis of neck/shoulder Pain and Low Back Pain with the Use of Digital Products, Physical Activity and Psychological Status among Adolescents in Shanghai. *PLOS ONE, 8*(10), e78109. https://doi.org/10.1371/JOURNAL.PONE.0078109.

Smith, S. M., Sumar, B., & Dixon, K. A. (2013). Musculoskeletal pain in overweight and obese children. *International Journal of Obesity 38*(1), 11–15. https://doi.org/10.1038/ijo.2013.187.

Steffens, D., Hancock, M. J., Maher, C. G., Williams, C., Jensen, T. S., & Latimer, J. (2014). Does magnetic resonance imaging predict future low back pain? A systematic review. *European Journal of Pain, 18*(6), 755–765. https://doi.org/10.1002/J.1532-2149.2013.00427.X.

Taylor, J. B., Goode, A. P., George, S. Z., & Cook, C. E. (2014). Incidence and risk factors for first-time incident low back pain: a systematic review and meta-analysis. *The spine journal: official journal of the North American Spine Society, 14*(10), 2299–2319. https://doi.org/10.1016/j.spinee.2014.01.026

Trigueiro, M. J., Massada, L., & Garganta, R. (2013). Back pain in Portuguese schoolchildren: Prevalence and risk factors. *European Journal of Public Health, 23*(3), 499–503. https://doi.org/10.1093/eurpub/cks105.

Tsze, D. S., Hirschfeld, G., Dayan, P. S., Bulloch, B., & von Baeyer, C. L. (2018). Defining No Pain, Mild, Moderate, and Severe Pain based on the Faces Pain Scale – Revised and Color Analog Scale in Children with Acute Pain. *Pediatric Emergency Care, 34*(8), 537–544. https://doi.org/10.1097/PEC.0000000000000791.

CHAPTER IV

STUDY II . BALANCE AND POSTURE IN CHILDREN AND ADOLESCENTS: A CROSS-SECTIONAL STUDY

Nelson Azevedo[1] , José Carlos Ribeiro[2] and Leandro Machado[3]*

1 CICS, ISAVE, Faculdade de Desporto da Universidade do Porto, 4200-450 Porto, Portugal; nelson.azevedo@docente.isave.pt

2 CIAFEL, ITR, Faculdade de Desporto da Universidade do Porto, 4200-450 Porto, Portugal; jribeiro@fade.up.pt

3 CIFI2D, LABIOMEP, Faculdade de Desporto da Universidade do Porto, 4200-450 Porto, Portugal; lmachado@fade.up.pt

***** *Correspondence: lmachado@fade.up.pt*

Current Status: Published on Sensors.

Azevedo, N., Ribeiro, J. C., & Machado, L. (2022). Balance and Posture in Children and Adolescents: A Cross-Sectional Study. Sensors (Basel, Switzerland), 22(13), 4973. https://doi.org/10.3390/s22134973

ABSTRACT

Purpose: Balance and posture are two topics that have been extensively studied, although with some conflicting findings. Therefore, the aim of this work is to analyze the relationship between the postural angles of the spine in the sagittal plane and the stable static balance.

Methods: A cross-sectional study was conducted with children and adolescents from schools in northern Portugal in 2019. An online questionnaire was used to characterize the sample and analyze back pain. Spinal postural angle assessment (pelvic, lumbar, and thoracic) was performed using the Spinal Mouse®, while stabilometry assessment was performed using Namrol® Podoprint®. Statistical significance was set as $\alpha < 0.05$.

Results/conclusion: The results showed that girls have better balance variables. There is a weak correlation between the anthropometric variables with stabilometry variables and the postural angles. This correlation is mostly negative, except for the thoracic spine with anthropometric variables and the lumbar spine with BMI. The results showed that postural angles of the spine are poor predictors of the stabilometric variables. Concerning back pain, increasing the postural angle of the thoracic spine increases the odds ratio of manifestation of back pain by 3%.

Keywords: Children; Adolescents; Posture; Balance; Back pain

INTRODUCTION

There are several definitions of good posture (Kauffman, 2007; Latash & Zatsiorsky, 2016), but Kendal et al. have presented a definition that we found interesting: "good posture is that state of muscular and skeletal balance which protects the supporting structures of the body against the injury or progressive deformity, irrespective of the attitude (erect, lying, squatting or stooping) in which these structures are working or resting. Under such conditions, the muscles will function most efficiently, and the optimum positions are afforded for the thoracic and abdominal organs" (Kendall & Kendall, 2005). Posture cannot be considered only as a static reflex response but is rather a complex competence based on the interaction of sensory-motor processes.

The effects of postural changes on health are not limited to adults but are also present in children. These effects are increasingly well described in the literature, and there is evidence of associated risk factors (Calvo-Muñoz et al., 2018a).

Understanding the relationship between posture and balance in children and adolescents is becoming increasingly important today due to lifestyle changes and their interrelationship with other musculoskeletal pathologies (Szita et al., 2018).

Balance involves the coordination of sensorimotor strategies to stabilize the body's center of pressure (CoP) in the presence of both self-initiated and externally-initiated disturbances of stability (Horak, 2006a). Balance control can be defined as the appropriate response to perturbations of the center of pressure caused by the oscillation of the center of gravity, motor activity, or conscious interaction with the environment (Błaszczyk et al., 2020).

Balance can be divided into four types, namely: stable static balance (i.e., maintaining a stable position while standing), stable dynamic balance (i.e., maintaining a stable position while walking), proactive balance (i.e., anticipating a predicted balance disturbance), and reactive balance (i.e., compensating for an unforeseen balance disturbance) (Shumway-Cook & Woollacott, 2007).

However, when we talk about balance and its relationship with gravity, we must necessarily talk about the foot. The foot contributes to the maintenance of postural stability by providing mechanical support to the body through the arch of the foot, among other structures, and coordinated coactivation of the lower limb muscles, as well as sensory information about body position and proprioception of the plantar cutaneous mechanoreceptors (Menz et al., 2005)**.**The importance of the foot and its relationship to the spine and back pain is becoming increasingly important (Menz et al., 2013).

For efficient balance control, it is necessary for the spine to have postural competence.

Spinal postural competence can be defined as the equilibrium between the external forces acting on the spine and the muscular response of the trunk, which is sensory regulated to maintain a stable upright posture, both static and dynamic (Abelin-Genevois, 2021; Lamartina & Berjano, 2014). Therefore, the relationship between the foot to provide sensory information and the spine is critical for optimal posture and efficient balance control, both in adults and children (Zurawski et al., 2020).

Recent studies have not found a direct relationship between children's posture and balance disorders (Ludwig, 2017; Ludwig et al., 2020)**.** Ludwig et al. (Ludwig et al., 2020) suggested that balance and posture are complex interdependent mechanisms that should be better studied and understood. The study by Zurawski et al. (Zurawski et al., 2020) found a relationship between posture and balance in children and adolescents. Posture is also related to the occurrence of back pain in children, and it is considered a triggering risk factor (Minghelli et al., 2014; Trigueiro et al., 2013a)**.**

Several studies included in a review article associate manifestations of back pain in adult subjects with balance deficits assessed by CoP stability parameters measured with pressure platforms (Ruhe et al., 2011)**.**

From all these literature results, it becomes apparent the relationship between posture and balance is an important topic for study and deeper understanding in children.

With the present study, we aim to deepen the understanding of the relationship between children's and adolescents' balance and changes in their posture in the sagittal plane.

To our knowledge, there is no study that examines the relationship between balance and posture using the pressure platform and the Spinal Mouse. By linking these two assessment tools, we expect to further explore this relationship between balance and posture.

Hypotheses:

H1: There is a relationship between postural angles in the spine regions with stable static balance in children and adolescents.

H2: There is an association between postural angles in the spine regions and stable static balance with the manifestation of back pain in children and adolescents.

MATERIALS AND METHODS

A cross-sectional study was carried out with children and adolescents from schools in the north of Portugal, in the district of Braga, between October and December 2019, comprising the beginning of the school year.

A population analysis was performed to calculate the sample size. In 2019, the number of students enrolled from the 5th to the 12th grade in mainland Portugal was 576436 (PORDATA - Alunos Matriculados: Total e Por Nível de Ensino, n.d.). With this population, the minimum size required for our study was 1066, with a margin of error of 3% and a confidence interval of 95% (Sample Size Calculator, n.d.). The study proposal was presented to the school director as well as to the physical education department. The benefits and potential risks of the study were explained. After approval of the study, we provided all children and adolescents in the school cluster with a description of the study and the informed consent form. All participants had the opportunity to participate or withdraw. After a period of analysis by the parents and legal guardians of the children, in which it was possible to clarify all doubts and questions related to the study, namely the benefits/risks, we obtained the written informed consent of all parents and guardians of the children involved in the study. The adults who participated in the study also signed the written informed consent.

Exclusion criteria were defined as participants who had musculoskeletal deficiencies or serious medical conditions that made data collection difficult or impossible.

The study design is shown in Figure 2.

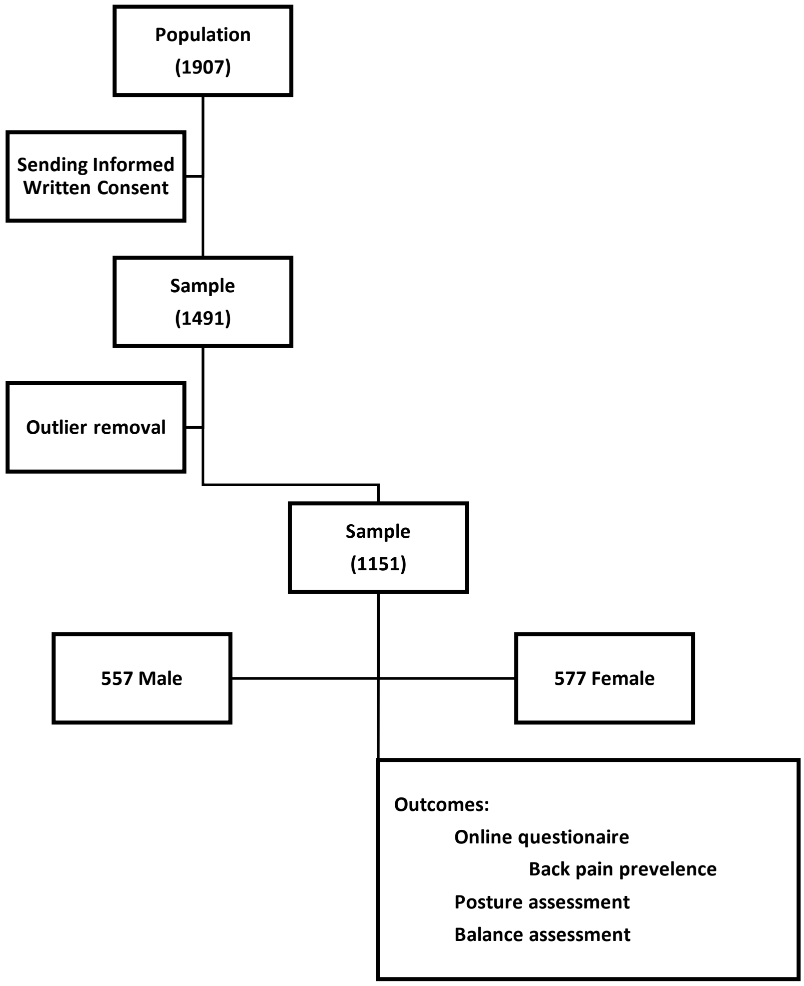

Figure 4.1. Study diagram.

Instruments.

An online questionnaire (Google Forms) was used to characterize the sample in terms of back pain and its severity. The questionnaire included questions about the location of back pain and its occurrence. An 11-item numerical scale (NRS-11) linked to the Face Pain Scale-Revised was used to quantify pain. This instrument is recommended for self-report in children and adolescents, and the combination of the two instruments makes it easier for children to describe their pain (Tomlinson et al., 2010).

Body mass index (BMI) was determined from the mass and height of the participants.

Postural angle assessment in the spinal regions was performed using the Spinal Mouse® (Idiag, Voletswil, Switzerland). The Spinal Mouse (SM) is a non-invasive mobility device used to quantify posture and spinal mobility. The spinal regions studied were the thoracic spine, lumbar spine, and pelvic region. The cervical spine was not included in the assessment because cervical spine measurements are not valid according to the manufacturer.

The software used with SM was IDIAG M360pro® version 7.6 (Idiag, Voletswil, Switzerland). An internal algorithm converts raw measurements into clinically relevant data, namely thoracic kyphosis, lumbar lordosis, and pelvic tilt angles.

The stable static balance evaluation was performed with a pressure platform to obtain the stabilometry parameters. The platform used was the Namrol® Podoprint® printing platform (Medicapteurs France SAS, Balma, France). The overall size of the platform is 610 x 580 x 9 mm for a 400 x 400 mm working surface with 1600 sensors (1 per cm^2). The software used was Podoprint software (Medicapteurs France SAS, Balma, France).

Posture Assessment.

Measurements were performed with the students in the orthostatic reference position and with minimal clothing in the trunk (the girls used adhesive tape to hold their bras, always assisted by the researcher and a female teacher; the boys had the torso without clothes). The assessment was conducted individually to preserve the privacy of each person assessed. Postural analysis in orthostatic position was performed by moving the Spinal Mouse along the spine of the subjects from the 7th cervical vertebra to the 2nd sacral vertebra. The assessment took place in a room reserved for this purpose, where privacy was maintained and which offered appropriate environmental conditions, especially in terms of temperature (about 22° C) and brightness. The privacy of the students was always maintained by having a screen-separate place for the analysis. The average duration of each examination was approximately 5 min per participant. For evaluation of the lumbar and thoracic spine angles, the respective Cobb angles in the sagittal plane are considered the gold standard (Wu et al., 2014), mainly in children (Chernukha et al., 1998).

For the evaluation of the thoracic kyphosis angle, the Cobb angle is measured by drawing a line through the upper endplate of T4 and a second line through the lower endplate of T12 (Koelé et al., 2020). For the evaluation of the lumbar lordosis angle, the Cobb angle is measured by drawing a line through the upper surface of the first lumbar vertebra and a second line through the surface of the first sacral vertebra (Skaf et al., 2011). Assessment of the sacrum was performed by pelvic tilt angle in the sagittal plane. The pelvic tilt is measured by the angle between the vertical and the line connecting the center of the upper sacral plate to the hip axis. There is a strong correlation between pelvic morphology and sacrum morphology and pelvic tilt (Mac-Thiong et al., 2007). As mentioned before, the thoracic kyphosis, lumbar lordosis, and pelvic tilt angles were all computed within the IDIAG M360pro® software from Spinal Mouse data and reported by the software (Guermazi et al., 2006; Kellis et al., 2008; Mannion et al., 2004). The reference angles for spinal curvatures in the sagittal plane in healthy children are thoracic kyphosis (33.3 ± 2.4) and lumbar lordosis L1–L5 (39.6 ± 2.6). The reference angles for adolescents for the same regions are thoracic kyphosis (35.4 ± 1.9) and lumbar lordosis L1–L5 (42.7 ± 1.5) (Furlanetto et al., 2018). The reference values for pelvic tilt in children and adolescents are 7.7 ± 8.3 (Mac-Thiong et al., 2011).

Balance Assessment

The stable static balance evaluation was performed with a pressure platform to obtain the stabilometry parameters. The data collected were the CoP sway path length (Sway path CoP), CoP ellipse area/surface displacement (Area CoP), CoP mean velocity displacement (v CoP), CoP lateral/medial mean velocity displacement (vML CoP), CoP anterior/posterior mean velocity displacement (vAP CoP), CoP lateral/medial total displacement (dML CoP), and CoP Anterior/Posterior total displacement (dAP CoP). Children were placed on the print platform for a period of 10 s and were asked to fixate a point in front of the wall. Due to the large sample size and because the subjects were children, we decided to use a shortened analysis period (10 s). This reduced time period has been used in other studies with clinical significance (Hunt et al., 2014). The assessment was performed with eyes open only. The balance assessment took place in a separate room from the posture assessment, but this room also provided the environmental and privacy conditions necessary for the comfort of the children and adolescents as well as for the evaluation.

Statistical Analysis

Descriptive statistics were used to characterize the study sample. Normality of conditions was assessed with the Kolmogorov–Smirnov test, and an analysis of outliers was performed for all variables included in the study to remove them from the statistical analysis.

Mann–Whitney U-test was used to estimate differences in the studied variables between the two gender groups (female/male).

The differences between the age groups (children and adolescents) and the studied variables were assessed using the independent-samples Mann–Whitney U-test.

To analyze the correlation between postural angles and stable static balance variables with the anthropometric variables, Pearson's correlation test was used.

Multiple linear regression was used to test if postural angles in the spine regions significantly predicted stable static balance variables in children and adolescents.

For the association between the manifestation of spinal pain and the variables studied, binary logistic regression was used to calculate the odds ratio. Statistical significance was set at $\alpha = 0.05$. The software IBMSPSS (IBMCorp, Armonk, NY, USA, version 26) was used.

RESULTS

The total number of students who were given informed consent after the description of the study was 1907, of whom 1491 agreed to participate in the study, comprising 729 female (48.9%) and 762 male (51.1%).

After analyzing the data, the outliers from the variables included in the study were removed, leaving 1154 individuals in the sample. Of these, 557 (50%) were male, and 577 (50%) were female.

Analyzing the results shown in Table 4.1, we can note that there are no differences between genders in terms of age (p-value > 0.877) and in the dAP CoP (p-value > 0.113), but in the other variables studied, these differences are significant. In anthropometric variables, males have higher values in almost all variables studied, except for BMI, where females have higher values. In the stabilometric variables, female individuals have lower values compared to male individuals. This relationship changes when comparing the variables of postural angles of the different regions of the spine, with female individuals showing higher values in all spinal segments studied. The values for the stabilometric variables are smaller than usual due to the small time used in the evaluation, just 10s, due to the reasons already mentioned in balance assessment.

Table 4.1. Sample characterization, stabilometric and angular variables, separated by gender. Comparison between genders for all variables.

	Female	**Male**	***p*-value***
	Mean/ SD	Mean/SD	
Age (yr)	14.16/ 2.29	14.16/ 2.26	0.877
Mass (kg)	54.53/ 11.59	57.33/ 13.29	**<0.001**
Height (cm)	158.23/ 8.53	165.27/ 13.28	**0.000**
BMI (kg/m^2)	21.65/ 3.50	20.77/ 3.11	**<0.001**
Sway path CoP(mm)	17.02/ 6.87	18.85/ 6.76	**<0.001**
Area CoP (mm^2)	10.35/ 8.89	11.29/ 8.23	**0.001**
v CoP (mm/s)	1.57/ 0.64	1.74/ 0.63	**<0.001**
vML CoP (mm/s)	1.18/ 0.51	1.32/ 0.52	**<0.001**
vAP CoP (mm/s)	1.02/ 0.44	1.11/ 0.42	**<0.001**
dML CoP (mm)	0.82/ 0.43	0.89/ 0.42	**0.003**
dAP CoP (mm)	0.92/ 0.49	0.96/ 0.48	**0.113**
Pelvic tilt (°)	20.45/ 6.09	15.25/ 5.48	**0.000**
Lumbar lordosis (°)	35.05/ 7,73	27.66/ 7.49	**<0.001**
Thoracic kyphosis (°)	47.32/ 9.78	45.31/ 8.50	**0.000**

The values for the stabilometric variables are smaller than usual mainly due to the small time used in the evaluation, just 10s, due to the reasons already mentioned in balance assessment.

We divided the total sample into age-related groups, namely children and adolescents following Furlanetto et al. (Furlanetto et al., 2018). The adults (18 and over in Furlanetto et al. classification) were only 25, and their parameters were indistinguishable statistically from those of the adolescents; therefore, we have merged the adults (25 subjects) into the adolescents' group. Comparing the studied variables with age-dependent groups (Table 4.2), the stabilometry values are higher in children compared to adolescents for all studied stabilometry parameters.

Table 4.2. Sample characterization, stabilometric and angular variables, separated by groups: children's and adolescents.

Age	**9-11**	**12-19**	***p*-value***
Number of subjects	195	959	
	Mean/ SD	Mean/SD	
Mass (kg)	42.92/10.40	58.57/11.23	**0.000**
Height (cm)	146.98/8.36	164.75/9.85	**0.000**
BMI (kg/m^2)	19.64/3.36	21.53/3.24	**<0.001**
Sway path CoP(mm)	21.83/6.42	17.14/6.69	**0.000**
Area CoP (mm^2)	14.94/9.38	9.98/8.16	**<0.001**
v CoP (mm/s)	2.01/0.60	1.58/0.62	**0.000**
vML CoP (mm/s)	1.52/0.52	1.19/0.50	**0.001**
vAP CoP (mm/s)	1.29/0.41	1.02/0.42	**0.001**
dML CoP (mm)	1.01/0.43	0.82/0.42	**<0.001**
dAP CoP (mm)	1.13/0.51	0.90/0.47	**<0.001**
Pelvic tilt (°)	17.12/4.81	18.00/6.61	0.075
Lumbar lordosis (°)	30.64/7.76	31.50/8.59	0.222
Thoracic kyphosis (°)	44.42/9.69	46.70/9.07	**0.002**

In the postural angle of the thoracic spine, children have a lower postural angle than adolescents.

The correlation of the anthropometric variables against the stabilometry variables and the postural angles (Table 4.3) shows a weak correlation between the variables, although it is statistically significant except for the correlation between lumbar angles and age and weight. The correlations are negative for almost all variables, except for thoracic angles against all anthropometric variables and lumbar angles in their correlation with BMI. All these correlations are small but significant.

Table 4.3. Pearson correlation between anthropometric variables and stabilometry and angular variables.

	Age (r)	Weight (r)	Height (r)	BMI (r)
Sway path CoP	-0.238**	-0.163**	-0.164**	-0.111**
Area CoP	-0.292**	-0.139**	-0.147**	-0.082**
v CoP	-0.287**	-0.158**	-0.160**	-0.107**
vML CoP	-0.279**	-0.162**	-0.158**	-0.115**
vAP CoP	-0.265**	-0.137**	-0.145**	-0.087**
dML CoP	-0.190**	-0.135**	-0.108**	-0.108**
dAP CoP	-0.191**	-0.108**	-0.125**	-0.053**
Pelvic tilt	0.077**	-0.092**	-0.130**	-0.003
Lumbar lordosis	0.053	-0.010	-0.108**	0.102**
Thoracic kyphosis	0.123**	0.307**	0.136**	0.339**

Table 4.4 shows the results of the multiple linear regression in which we tested whether the postural angles of the different regions studied significantly predicted the stabilometry results. A model of the following form was used:

$$Y = C0 + B1 * \text{Pelvic} + B2 * \text{Thoracic} + B3 * \text{Lumbar} + e$$

Table 4.4. Multiple linear regression between the angles of sagittal spinal posture and the stabilometric variables.

	B	95% CI	β	*t*	***p*-value**
Sway path CoP (R^2 = 0.03, F (3, 1150) =10.36, p = < 0.001)					
Constant	23.591	21.207, 25.975		19.414	**<0.001**
Pelvic Tilt	-0.226	-0.356, -0.097	-0.209	-3.425	**<0.001**
Lumbar lordosis	0.069	-0.038, 0.175	0.085	1.270	0.204
Thoracic kyphosis	-0.081	-0.140, -0.023	-0.109	-2.713	**0.007**
Area CoP (R^2 = 0.01, F (3, 1150) =3.18, p = 0.023)					
Constant	14.623	11.621, 17.624		9.559	**<0.001**
Pelvic Tilt	-0.171	-0.334, -0.008	-0.127	-2.056	**0.040**
Lumbar lordosis	0.059	-0.075, 0.193	0.058	0.863	0.388

Thoracic kyphosis	-0.056	-0.130, ,0.18	-0.060	-1.480	0.139
v CoP (R^2 = 0.03, F (3, 1150) =10.31, p < 0.001)					
Constant	2.178	1.956, 2.400		19.258	**<0.001**
Pelvic Tilt	-0.021	-0.033, -0.009	-0.211	-3.454	**<0.001**
Lumbar lordosis	0.007	-0.003, 0.016	0.087	1.301	0.194
Thoracic kyphosis	-0.008	-0.013, -0.002	-0.109	-2.698	**0.007**
vML CoP (R^2 = 0.02, F (3, 1150) =8.96, p < 0.001)					
Constant	1.657	1.476, 1.837		17.992	**<0.001**
Pelvic Tilt	-0.018	-0.027, -0.008	-0.215	-3.513	**<0.001**
Lumbar lordosis	0.007	-0.001, 0.015	0.111	1.657	0.098
Thoracic kyphosis	-0.007	-0.011, -0.002	-0.117	-2.901	**0.004**
vAP CoP (R^2 = 0.02, F (3, 1150) =8.99, p < 0.001)					
Constant	1.387	1.236, 1.538		18.053	**<0.001**
Pelvic Tilt	-0.013	-0.021, -0.004	-0.185	-3.035	**0.002**
Lumbar lordosis	0.003	-0.004, 0.010	0.063	0.937	0.349
Thoracic kyphosis	-0.004	-0.008, -0.001	-0.091	-2.259	**0.024**
dML CoP (R^2 = 0.01, F (3, 1150) =3.68, p = 0.012)					
Constant	1.070	0.921, 1.218		14.098	**<0.001**
Pelvic Tilt	-0.011	-0.019, -0.003	-0.168	-2.737	**0.006**
Lumbar lordosis	0.007	0.000, 0.014	0.137	2.033	**0.042**
Thoracic kyphosis	-0.005	-0.009, -0.001	-0.108	-2.665	**0.008**
dAP CoP (R^2 = 0.004, F (3, 1150) =1.46, p = 0.223)					
Constant	1.095	0.925, 1.265		12.644	**<0.001**
Pelvic Tilt	-0.003	-0.012, 0.006	-0.039	-0.629	0.529
Lumbar lordosis	-0.001	-0.008, 0.007	-0.012	-0.185	0.853
Thoracic kyphosis	-0.002	-0.006, 0.002	-0.033	-0.808	0.419

When analyzing the results, it was found that the fit of the postural angles to predict the stabilometry values had very low values of the coefficient of determination (R2);

that is, the fit is very poor. This can be seen in Figure 4.2, where an example for the Sway path CoP is shown. The coefficients of the fit (B_1, B_2, B_3) also have very small values, implying that the fit is almost just the constant value (C_0), i.e., a horizontal line.

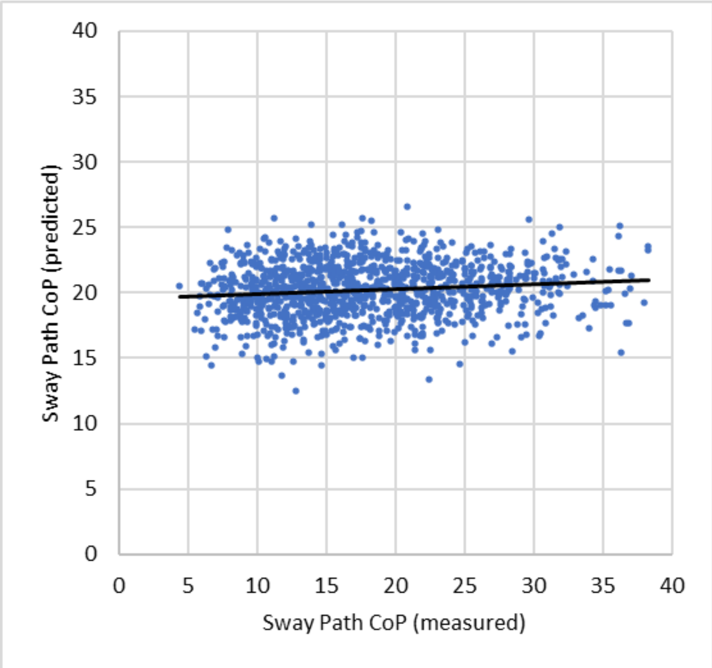

Figure 4.2. Scatterplot of the predicted (from Table 3 values) over the measured Sway Path CoP. The black line is a linear fit of the plotted points, just to help in the visualization.

Most of the fits, and most of the fitting coefficients, have statistically significant values. Nevertheless, fittings are very poor.

In our data, Table 4.5, binary logistic regression indicates that the angle of thoracic kyphosis is the only significant predictor of back pain in children and adolescents (Chi-Square = 41.49, df = 10 and p = 0.001). The other nine variables were not significant against back pain. The postural angle of the thoracic spine explains only 3% of the manifestation of back pain in children and adolescents, but it is a significant relationship. The greater the thoracic kyphosis, the greater the risk of back pain (OR: 1.030; CI 1.011–1.048).

Table 4.5. Manifestation of back pain against balance and posture parameters.

	Odds Ratio	95% CI	*p*-value
Sway path CoP	1.026	0.760/ 1.385	0.867
Area CoP	0.988	0.951/ 1.026	0.520
v CoP	0.644	0.028/ 14.819	0.783
vML CoP	0.748	0.077/ 7.273	0.802
vAP CoP	1.186	0.152/ 9.276	0.871
dML CoP	1.381	0.827/ 2.308	0.217
dAP CoP	0.901	0.578/ 1.404	0.644
Pelvic tilt	1.027	0.987/ 1.069	0.184
Lumbar lordosis	0.997	0.965/ 1.030	0.854
Thoracic kyphosis	1.030	1.011/ 1.048	**0.002**

DISCUSSION

This study had two main objectives, reflected in two study hypotheses. The first objective was to evaluate the relationship between postural angles in the spine regions and stable static balance variables in children and adolescents. Our second objective was to investigate whether postural angles and stable static balance parameters are related to the manifestation of back pain.

For the first study hypothesis, we can conclude from the data analysis that the postural angles of the different regions of the spine, namely the thoracic, lumbar, and pelvic spine, give poor predictions of balance variables. Most of the fits were statistically significant, but all of them have values of R^2 very close to zero.

For the second hypothesis, through our analysis, we found one statistically significant relationship between the postural angle of the thoracic spine and the manifestation of back pain in children and adolescents. This risk increases with increasing the angle of thoracic kyphosis, although it is relatively small (3% OR). The other variables did not show a statistically significant association with the manifestation of back pain in children and adolescents. Posture is only one factor among the numerous factors associated with back pain in children and adolescents (Calvo-Muñoz et al., 2018; Minghelli et al., 2014).

Differences between Genders

The results of this study show something interesting regarding the difference between genders, namely that girls have lower values of the stabilimetry variables at stable static balance than boys. This observation may indicate the higher stability of the girls. This finding is consistent with the studies conducted by Rusek et al. (Rusek et al., 2021) and Ludwig et al. (Ludwig et al., 2020).

These observations have also been made in other studies in adults (Bryant et al., 2005; Sullivan et al., 2009), therefore, it will be important for future studies to examine more closely the neuromuscular patterns associated with gender differences.

Differences between Children and Adolescents

The division into age groups was based on Furlanetto et al. (Furlanetto et al., 2018). When comparing the results of stabilometry, it can be seen that balance increases with age, with children having a lower balance index than adolescents. These data are consistent with a systematic review that found that adolescents have higher balance scores compared with children (Schedler et al., 2019). Older children have higher height, which, according to a recent study analyzing anthropometric variables and balance, not only has negative correlation indices with balance variables, as seen in our study, but is also a predominant factor in explaining balance (Alonso et al., 2015; Graff et al., 2020).

The thoracic kyphosis curvature showed a linear increase with age, which has been confirmed in other studies seeking to understand the development of thoracic curvature with growth (Giglio & Volpon, 2007; Willner & Johnson, 1983).

Anthropometric Variables, Static Balance, and Posture

The negative relationship between anthropometric variables and stable static balance was observed for all variables analyzed (Table 3). This indicates that the higher the age, weight, height, or BMI, the lower the values of the stabilometry variables, suggesting for better sensorimotor abilities related to balance. Age is the variable with the highest negative correlation; that is, the older the child is, the better their balance is. These results are consistent with the data in Table 2, where a positive relationship was found between age and balance competence.

Results similar to those of height are found for weight and BMI but with lower correlation coefficients, although statistically significant. This fact may also be related to the fact that older young people have more weight. The BMI results are consistent with studies that have found a negative correlation between balance and BMI (Greve et al., 2007), and also are in line with the results of a recent study in which children and adolescents with higher BMI performed better on balance parameters (Rusek et al., 2021).

The results related to the correlation between the postural variables and the anthropometric variables showed a significant negative correlation between the pelvic tilt and the age, weight, and height, although the correlations are very low. The lumbar lordosis shows a significant correlation with height and BMI. For height, this correlation is negative, and for BMI, it is positive. This correlation is also very low but is consistent with the results of other studies (Jankowicz-Szymańska et al., 2019). For the data of the thoracic kyphosis, the correlation is positive for all variables, especially for weight and BMI, with the latter correlation being more significant. Thus, the higher the BMI, the greater the angle of thoracic kyphosis. These data are consistent with some studies highlighting the positive correlation between BMI and hyperkyphosis (Valdovino et al., 2019). Height also showed a positive correlation with the increase in the curvature of thoracic kyphosis, as already underscored in another study (Monteiro et al., 2019). Although the correlation is not as strong as for weight and BMI, it is also significant. This finding may help to better understand the occurrence of hyperkyphosis in children and adolescents.

Posture and Balance

In our study, the postural angles of the three spinal regions studied, namely the pelvic tilt, the lumbar lodosis, and the thoracic kyphosis, have shown to be poor predictors of the stabilometric variables. This predictive relationship, although statistically significant, has very low values of R^2 for all relationships between variables. These data show a marginal relationship between postural changes and changes in static balance, although other studies have not found a significant correlation between these variables (Ludwig, 2017; Ludwig et al., 2020).

This relationship raises some questions about the normal development of children's motor skills and posture. A study conducted by Nagymáté et al. (Nagymáté et al., 2018) concluded that poor posture in children has no clear effect on balance. Another study investigated the relationship between balance and postural changes in the sagittal plane of the spine and concluded that increases in lumbar lordosis lead to a worsening of the ability to tolerate balance disturbances (Kurzeja et al., 2022). Also in our study, the increase in lumbar lordosis was associated with the increase in dML CoP, leading to a decrease in balance, and although statistically significant, it was a very small increase (linear fit coefficient of 0.007).

Another interesting result relates to pelvic tilt and its relationship to balance. Of all the parameters related to postural angles, pelvic tilt is the one most related to balance (although the relationship is small), in this case negative. When the anterior pelvic tilt increases, the stabilometry parameters decrease, suggesting better balance. These results are consistent with those from Mac-Thiong et al. (Mac-Thiong et al., 2004), study, which showed that pelvic tilt increases with age, most likely to avoid an insufficient anterior shift of the body's center of gravity.

Back Pain and Balance Parameters

Among the studies that tried to identify the risk factors that influence back pain in children and adolescents, the use of posture variables is common, but their relationship with a balance is not fully clarified (Calvo-Muñoz et al., 2018; Kamper et al., 2016).

In our study, the variables related to static balance did not contribute to an increase in the probability of having back pain. However, when we analyze the postural angles and their relationship with the manifestation of back pain, this relationship is significant for thoracic kyphosis. The greater the angle of the thoracic kyphosis, the greater the risk of back pain. Although this increment is low, it is significant. There have been several studies addressing back pain and the lumbar lordosis, particularly low back pain (Calvo-Muñoz et al., 2013; Kędra et al., 2021; Yang et al., 2017), but the association with thoracic spine postural angle as a predictor of back pain has been little studied, except in more severe clinical conditions such as Scheuermann’s disease (Karpe et al., 2020; Palazzo et al., 2014).

Although there is no consensus on the risk factors for back pain in children and adolescents, posture seems to be an important factor, especially sitting posture (Calvo-Muñoz et al., 2018; Sainz de Baranda et al., 2020; Trevelyan & Legg, 2006). In our study, assessment was performed in the upright position, and assessment of posture in this position is also a common clinical practice. These data confirm that clinical posture assessment is an important tool for the early detection of potential risk factors related to posture itself and back pain.

Some other factors that may be related to back pain, such as the time spent using a smartphone or the time spent practicing physical exercises per week, will be the subject of a forthcoming article.

Practical Implications of the Study

Motor skills, especially balance in children, are essential for normal musculoskeletal development. Postural changes are increasingly evident in today’s society, where sedentary lifestyles and poor posture are on the rise. This study confirms the relationship between posture and balance. Although it is a weak relationship, it is significant. Therefore, we must work with schools and teachers to promote the importance of physical activity and exercise in physical education classes, where balance is a modality of increasing importance. This promotion must also include work on posture correction in the classroom so that the results related to prevention are more effective and sustainable.

Limitations of the Study

One of the principal limitations of this study is the short time used for the stabilometric evaluation, just 10 s. We selected this value due to the number of subjects to evaluate and the fact that a good fraction of them was very young, and it was difficult for them to stand still for longer periods. We believe this was the main cause of the lower than usual values for the stabilometric variables. Furthermore, this study has natural limitations characteristic of cross-sectional studies in understanding a phenomenon as complex as human balance and its relationship to spinal posture. Thus, although we can establish relationships between the parameters studied, we cannot establish direct causality between them in children and adolescents. It would be interesting to add other measurement tools, such as surface EMG, to analyze the muscle activity of the muscles involved in postural control, but the large sample size and the younger population (due to the characteristics of the children) would require a rigorous and rapid process of data collection, something not easy to apply in practice. Despite these limitations, we were able to contribute a little more to the understanding of the already complex relationship between balance and posture in the younger population.

CONCLUSION

With this work, we contribute to a more comprehensive understanding of the relationship between spinal postural angles and static balance in children and adolescents.

Postural changes in children and adolescents and the consequences of inefficient balance are becoming increasingly important in developing programs to prevent musculoskeletal pathologies in today's children.

Author Contributions: Conceptualization, N.A. and L.M.; methodology, N.A. and L.M.; validation, J.C.R. and L.M.; formal analysis, J.C.R. and L.M.; investigation, N.A. and L.M.; resources, N.A., J.C.R. and L.M.; data curation, N.A.; writing—original draft preparation, N.A.; writing—review and editing, L.M., N.A. and J.C.R.; visualization, L.M. and N.A.; supervision, L.M. and J.C.R.; project administration, L.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

*Institutional Review Board Statement***:** This study was carried out in accordance with the guidelines in the Declaration of Helsinki, and all participants participating in the study were approved by the ethics committee of FADEUP—Universidade do Porto (CEFADE 50).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Informed consent was obtained from parents or guardians of study participants under 18 years of age. Adult participants (18 or 19 years of age) gave their own informed consent.

Data Availability Statement: The data underlying this study are available from the corresponding author upon request.

Acknowledgments: We would like to thank the Padre Benjamim Salgado school group, as well as their general director and the physical education group. Their support was essential to carrying out the study. We would also like to thank the children and adolescents and their parents and legal representatives for their willingness to participate in the study.

Conflicts of Interest: The authors declare no conflict of interest.

REFERENCES

Abelin-Genevois, K. (2021). Sagittal balance of the spine. *Orthopaedics & Traumatology: Surgery & Research, 107*(1), 102769. https://doi.org/10.1016/J.OTSR.2020.102769.

Alonso, A. C., Mochizuki, L., Silva Luna, N. M., Ayama, S., Canonica, A. C., & Greve, J. M. (2015). Relation between the Sensory and Anthropometric Variables in the Quiet Standing Postural Control: Is the Inverted Pendulum Important for the Static Balance Control?. *BioMed research international, 2015,* 985312. https://doi.org/10.1155/2015/985312

Błaszczyk, J. W., Fredyk, A., Błaszczyk, P. M., & Ashtiani, M. (2020). Step Response of Human Motor System as a Measure of Postural Stability in Children. *IEEE Transactions on Neural Systems and Rehabilitation Engineering : A Publication of the IEEE Engineering in Medicine and Biology Society, 28*(4), 895–903. https://doi.org/10.1109/TNSRE.2020.2974784.

Bryant, E. C., Trew, M. E., Bruce, A. M., Kuisma, R. M., & Smith, A. W. (2005). Gender differences in balance performance at the time of retirement. *Clinical biomechanics (Bristol, Avon), 20*(3), 330–335. https://doi.org/10.1016/j.clinbiomech.2004.11.006.

Calvo-Muñoz, I., Gómez-Conesa, A., & Sánchez-Meca, J. (2013). Prevalence of low back pain in children and adolescents: a meta-analysis. *BMC pediatrics, 13*, 14. https://doi.org/10.1186/1471-2431-13-14.

Calvo-Muñoz, I., Kovacs, F. M., Roqué, M., Gago Fernández, I., & Seco Calvo, J. (2018). Risk Factors for Low Back Pain in Childhood and Adolescence: A Systematic Review. *The Clinical journal of pain, 34*(5), 468–484. https://doi.org/10.1097/AJP.0000000000000558.

Chernukha, K. V., Daffner, R. H., & Reigel, D. H. (1998). Lumbar lordosis measurement. A new method versus Cobb technique. *Spine, 23*(1), 74–80. https://doi.org/10.1097/00007632-199801010-00016.

Furlanetto, T. S., Sedrez, J. A., Candotti, C. T., & Loss, J. F. (2018). Reference values for Cobb angles when evaluating the spine in the sagittal plane: A systematic review with meta-analysis. *Motricidade, 14*(2–3), Article 2–3. https://doi.org/10.6063/motricidade.10890.

Giglio, C. A., & Volpon, J. B. (2007). Development and evaluation of thoracic kyphosis and lumbar lordosis during growth. *Journal of children's orthopaedics, 1*(3), 187–193. https://doi.org/10.1007/s11832-007-0033-5.

Graff, K., Szczerbik, E., Kalinowska, M., Jaworski, M., & Syczewska, M. (2020). Balance assessment in healthy children and adolescents aged 6-18 years based on six tests collected on AMTI AccuSway force platform. *Acta of bioengineering and biomechanics, 22*(2), 121–130.

Greve, J., Alonso, A., Bordini, A. C., & Camanho, G. L. (2007). Correlation between body mass index and postural balance. *Clinics (Sao Paulo, Brazil), 62*(6), 717–720. https://doi.org/10.1590/s1807-59322007000600010.

Guermazi, M., Ghroubi, S., Kassis, M., Jaziri, O., Keskes, H., Kessomtini, W., Ben Hammouda, I., & Elleuch, M. H. (2006). Validité et reproductibilité du Spinal Mouse pour l'étude de la mobilité en flexion du rachis lombaire [Validity and reliability of Spinal Mouse to assess lumbar flexion]. *Annales de readaptation et de medecine physique : revue scientifique de la Societe francaise de reeducation fonctionnelle* *de readaptation et de medecine physique, 49*(4), 172–177. https://doi.org/10.1016/j.annrmp.2006.03.001.

Horak F. B. (2006). Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? *Age and ageing, 35*(2), ii7–ii11. https://doi.org/10.1093/ageing/afl077.

Hunt, C. M., Widener, G., & Allen, D. D. (2014). Variability in postural control with and without balance-based torso- weighting in people with multiple sclerosis and healthy controls. *Physical therapy, 94*(10), 1489–1498. https://doi.org/10.2522/ptj.20130288.

Jankowicz-Szymańska, A., Bibro, M., Wodka, K., & Smola, E. (2019). Does Excessive Body Weight Change the Shape of the Spine in Children?. *Childhood obesity (Print), 15*(5), 346–352. https://doi.org/10.1089/chi.2018.0361.

Kamper, S. J., Yamato, T. P., & Williams, C. M. (2016). The prevalence, risk factors, prognosis and treatment for back pain in children and adolescents: An overview of systematic reviews. Best practice & research. *Clinical rheumatology, 30*(6), 1021–1036. https://doi.org/10.1016/j.berh.2017.04.003.

Karpe, P., Killen, M.-C., & Fender, D. (2020). Back pain in children. *Surgery (Oxford), 38*(9), 500–508. https://doi.org/10.1016/j.mpsur.2020.06.019.

Kauffman, T. L. (2007). Chapter 15—Posture. In T. L. Kauffman, J. O. Barr, & M. Moran (Eds.), *Geriatric Rehabilitation Manual (Second Edition)* (pp. 99–105). Churchill Livingstone. https://doi.org/10.1016/B978-0-443-10233-2.50022-5.

Kędra, A., Plandowska, M., Kędra, P., & Czaprowski, D. (2021). Physical activity and low back pain in children and adolescents: A systematic review. European *Spine Journal : Official Publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 30*(4), 946–956. https://doi.org/10.1007/S00586-020-06575-5.

Kellis, E., Adamou, G., Tzilios, G., & Emmanouilidou, M. (2008). Reliability of spinal range of motion in healthy boys using a skin-surface device. *Journal of manipulative and physiological therapeutics, 31*(8), 570–576. https://doi.org/10.1016/j.jmpt.2008.09.001.

Kendall, F. P., & Kendall, F. P. (Eds.). (2005). Muscles: Testing and function with posture and pain (5th ed). Lippincott Williams & Wilkins.

Koelé, M. C., Lems, W. F., & Willems, H. C. (2020). The Clinical Relevance of Hyperkyphosis: A Narrative Review. *Frontiers in endocrinology, 11*, 5. https://doi.org/10.3389/fendo.2020.00005.

Kurzeja, P., Gąsienica-Walczak, B., Ogrodzka-Ciechanowicz, K., & Prusak, J. (2022). Analysis of the Ability to Tolerate Body Balance Disturbance in Relation to Selected Changes in the Sagittal Plane of the Spine in Early School-Age Children. *Journal of Clinical Medicine, 11*(6), 1653. http://dx.doi.org/10.3390/jcm11061653

Lamartina, C., & Berjano, P. (2014). Classification of sagittal imbalance based on spinal alignment and compensatory mechanisms. *European Spine Journal, 23*(6), 1177–1189. https://doi.org/10.1007/s00586-014-3227-9.

Latash, M. L., & Zatsiorsky, V. M. (2016). 14—Posture. In M. L. Latash & V. M. Zatsiorsky (Eds.), *Biomechanics and Motor Control* (pp. 305–333). Academic Press. https://doi.org/10.1016/B978-0-12-800384-8.00014-4.

Ludwig, O. (2017). Interrelationship between postural balance and body posture in children and adolescents. *Journal of Physical Therapy Science, 29*(7), 1154–1158. https://doi.org/10.1589/JPTS.29.1154.

Ludwig, O., Kelm, J., Hammes, A., Schmitt, E., & Fröhlich, M. (2020). Neuromuscular performance of balance and posture control in childhood and adolescence. *Heliyon, 6*(7). https://doi.org/10.1016/J.HELIYON.2020.E04541.

Mac-Thiong, J. M., Berthonnaud, E., Dimar, J. R., 2nd, Betz, R. R., & Labelle, H. (2004). Sagittal alignment of the spine and pelvis during growth. *Spine, 29*(15), 1642–1647. https://doi.org/10.1097/01.brs.0000132312.78469.7b.

Mac-Thiong, J. M., Labelle, H., Berthonnaud, E., Betz, R. R., & Roussouly, P. (2007). Sagittal spinopelvic balance in normal children and adolescents. *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 16*(2), 227–234. https://doi.org/10.1007/s00586-005-0013-8.

Mac-Thiong, J. M., Labelle, H., & Roussouly, P. (2011). Pediatric sagittal alignment. *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 20*(5), 586–590. https://doi.org/10.1007/s00586-011-1925-0.

Mannion, A. F., Knecht, K., Balaban, G., Dvorak, J., & Grob, D. (2004). A new skin-surface device for measuring the curvature and global and segmental ranges of motion of the spine: Reliability of measurements and comparison with data reviewed from the literature. *European Spine Journal, 13*(2), 122–136. https://doi.org/10.1007/s00586-003-0618-8.

Menz, H. B., Dufour, A. B., Riskowski, J. L., Hillstrom, H. J., & Hannan, M. T. (2013). Foot posture, foot function and low back pain: The Framingham Foot Study. *Rheumatology (Oxford, England), 52*(12), 2275. https://doi.org/10.1093/RHEUMATOLOGY/KET298.

Menz, H. B., Morris, M. E., & Lord, S. R. (2005). Foot and ankle characteristics associated with impaired balance and functional ability in older people. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 60*(12), 1546–1552. https://doi.org/10.1093/GERONA/60.12.1546.

Minghelli, B., Oliveira, R., & Nunes, C. (2014). Non-specific low back pain in adolescents from the south of Portugal: Prevalence and associated factors. *Journal of Orthopaedic Science, 19*(6), 883–892. https://doi.org/10.1007/s00776-014-0626-z.

Monteiro, A., Silva, J., Sousa, S., Gonçalves, D., Azevedo, N., Rodrigues, L., & Pacheco, G. (2019). Height and Postural Deviations of the Spine in School-Age Children: Evaluation with Idiag® Spinal Mouse®. *European Journal of Public Health, 29*(1), ckz034.082. https://doi.org/10.1093/eurpub/ckz034.082.

Nagymáté, G., Takács, M., & Kiss, R. M. (2018). Does bad posture affect the standing balance? Cogent Medicine, 5(1), 1503778. https://doi.org/10.1080/2331205X.2018.1503778.

Palazzo, C., Sailhan, F., & Revel, M. (2014). Scheuermann's disease: an update. *Joint bone spine, 81*(3), 209–214. https://doi.org/10.1016/j.jbspin.2013.11.012.

PORDATA - Alunos matriculados: Total e por nível de ensino. (n.d.). Retrieved 9 April 2022, from https://www.pordata.pt/Portugal/Alunos+matriculados+total+e+por+n%c3%advel+de+ensino-1002.

Ruhe, A., Fejer, R., & Walker, B. (2011). Center of pressure excursion as a measure of balance performance in patients with non-specific low back pain compared to healthy controls: A systematic review of the literature. *European Spine Journal, 20*(3), 358–368. https://doi.org/10.1007/S00586-010-1543-2/TABLES/6.

Rusek, W., Adamczyk, M., Baran, J., Leszczak, J., Inglot, G., Baran, R., & Pop, T. (2021). Is There a Link between Balance and Body Mass Composition in Children and Adolescents?*. International journal of environmental research and public health, 18*(19), 10449. https://doi.org/10.3390/ijerph181910449.

Sainz de Baranda, P., Cejudo, A., Martínez-Romero, M. T., Aparicio-Sarmiento, A., Rodríguez-Ferrán, O., Collazo-Diéguez, M., Hurtado-Avilés, J., Andújar, P., & Santonja-Medina, F. (2020). Sitting Posture, Sagittal Spinal Curvatures and Back Pain in 8 to 12-Year-Old Children from the Region of Murcia (Spain): ISQUIOS Programme. *International journal of environmental research and public health, 17*(7), 2578. https://doi.org/10.3390/ijerph17072578.

Sample Size Calculator. (n.d.). Retrieved 9 April 2022, from https://www.calculator.net/sample-size-calculator.html.

Schedler, S., Kiss, R., & Muehlbauer, T. (2019). Age and sex differences in human balance performance from 6-18 years of age: A systematic review and meta-analysis. *PloS one, 14*(4), e0214434. https://doi.org/10.1371/journal.pone.0214434.

Shumway-Cook, A., & Woollacott, M. H. (2007). *Motor control: Translating research into clinical practice*. 612.

Skaf, G. S., Ayoub, C. M., Domloj, N. T., Turbay, M. J., El-Zein, C., & Hourani, M. H. (2011). Effect of age and lordotic angle on the level of lumbar disc herniation. *Advances in orthopedics,* 2011, 950576. https://doi.org/10.4061/2011/950576.

Sullivan, E. V., Rose, J., Rohlfing, T., & Pfefferbaum, A. (2009). Postural sway reduction in aging men and women: relation to brain structure, cognitive status, and stabilizing factors. *Neurobiology of aging, 30*(5), 793–807. https://doi.org/10.1016/j.neurobiolaging.2007.08.021.

Szita, J., Boja, S., Szilagyi, A., Somhegyi, A., Varga, P. P., & Lazary, A. (2018). Risk factors of non-specific spinal pain in childhood. *European Spine Journal, 27*(5), 1119–1126. https://doi.org/10.1007/s00586-018-5516-1.

Tomlinson, D., von Baeyer, C. L., Stinson, J. N., & Sung, L. (2010). A systematic review of faces scales for the self-report of pain intensity in children. *Pediatrics, 126*(5), e1168–e1198. https://doi.org/10.1542/peds.2010-1609.

Trevelyan, F. C., & Legg, S. J. (2006). Back pain in school children--where to from here?. *Applied ergonomics, 37*(1), 45–54. https://doi.org/10.1016/j.apergo.2004.02.008.

Trigueiro, M. J., Massada, L., & Garganta, R. (2013). Back pain in Portuguese schoolchildren: Prevalence and risk factors. The European Journal of Public Health, 23(3), 499–503. https://doi.org/10.1093/eurpub/cks105.

Valdovino, A. G., Bastrom, T. P., Reighard, F. G., Cross, M., Bartley, C. E., Shah, S. A., Yaszay, B., Newton, P. O., & Upasani, V. V. (2019). Obesity Is Associated With Increased Thoracic Kyphosis in Adolescent Idiopathic Scoliosis Patients and Nonscoliotic Adolescents. *Spine deformity, 7*(6), 865–869. https://doi.org/10.1016/j.jspd.2019.03.010.

Willner, S., & Johnson, B. (1983). Thoracic kyphosis and lumbar lordosis during the growth period in children. *Acta paediatrica Scandinavica, 72*(6), 873–878. https://doi.org/10.1111/j.1651-2227.1983.tb09833.x.

Wu, W., Liang, J., Du, Y., Tan, X., Xiang, X., Wang, W., Ru, N., & Le, J. (2014). Reliability and reproducibility analysis of the Cobb angle and assessing sagittal plane by computer-assisted and manual measurement tools. *BMC Musculoskeletal Disorders, 15*(1), 33. https://doi.org/10.1186/1471-2474-15-33.

Yang, S., Werner, B. C., Singla, A., & Abel, M. F. (2017). Low Back Pain in Adolescents: A 1-Year Analysis of Eventual Diagnoses. *Journal of pediatric orthopedics, 37*(5), 344–347. https://doi.org/10.1097/BPO.0000000000000653.

Zurawski, A. L., Kiebzak, W. P., Kowalski, I. M., Sliwinski, G., & Sliwinski, Z. (2020). Evaluation of the association between postural control and sagittal curvature of the spine. *PLoS ONE, 15*(10). https://doi.org/10.1371/JOURNAL.PONE.0241228.

CHAPTER V

STUDY III . IS FLEXIBILITY ASSOCIATED WITH BODY COMPOSITION? BIOIMPEDANCE ANALYSIS IN CHILDREN AND ADOLESCENTS.

Nelson Azevedo[1]*, José Carlos Ribeiro[2] and Leandro Machado[3]

1 CICS, ISAVE, Faculdade de Desporto da Universidade do Porto, 4200-450 Porto, Portugal; nelson.azevedo@docente.isave.pt

2 CIAFEL, ITR, Faculdade de Desporto da Universidade do Porto, 4200-450 Porto, Portugal; jribeiro@fade.up.pt

3 CIFI2D, LABIOMEP, Faculdade de Desporto da Universidade do Porto, 4200-450 Porto, Portugal: lmachado@fade.up.pt

***** *Correspondence: nelson.azevedo@docente.isave.pt*

Current Status: Published on Advances and Current Trends in Biomechanics

Azevedo, N., Ribeiro, J. C., Machado, L. (2021) Is flexibility associated with body composition? Bioimpedance analysis in children and adolescents. In Belinha, J., Campos, J.C.R., Fonseca, E., Silva, M.H.F., Marques, M.A., Costa, M.F.G, & Oliveira, S. (Eds), Advances and current trends in biomechanics: Proceedings of the 9th Portuguese Congress on Biomechanics, February 19 – 20, 2021, Porto, Portugal (pp. 299-303). Taylor & Francis. https:// doi: 10.1201/9781003217152-66.

ABSTRACT

Background: Flexibility is an important parameter of musculoskeletal assessment. It is related to sports performance, but also to health conditions. Flexibility is part of the characterization of the global physical fitness of children and adolescents, as is the assessment of body composition. There is a scarce literature reporting the association between the levels of flexibility and the variables related to body composition.

To understand the existence of an association between body composition and flexibility, a cross-sectional study in children and adolescents was carried out using valid instruments to assess flexibility and body composition. The results suggest an association between bioimpedance values and flexibility, while observing differences between genders and ages.

Keywords: Flexibility, children, adolescents, physical fitness, body composition.

INTRODUCTION

Physical fitness analysis in children and adolescents is extremely important because it may serve as a predictor of future health in children, both in terms of cardiovascular diseases as well as musculoskeletal diseases, especially diseases of the spine (Ruiz et al., 2009). In Portugal, the benchmark for assessing physical fitness in the education system is through the FITescola® program. This program is divided into 3 specific areas, namely aerobic fitness, body composition and neuromuscular fitness. Flexibility is assessed in the neuromuscular fitness area. Flexibility is an important parameter for sports evaluation (Arnason et al., 2004), but also for musculoskeletal health (Martim and Simas, 2012). The benefits of a good physical fitness level are not only limited to the physical component but also to the quality of life in children (Garber et al., 2011). There are several factors that contribute to the different levels of flexibility, including the parameters of body composition (Eler, 2018). Studies have found differences between genders and levels of flexibility (Haugen, Høigaard and Seiler, 2014; Eler, 2018), but there is little evidence of the association that body composition parameters have with flexibility in children and adolescents (Ganley et al., 2011).

MATERIALS AND METHODS

A cross-sectional study was carried out with children from some schools in the north of Portugal, in Braga district, between October and December 2019. As instruments, a sample characterization questionnaire, a body composition analyser (InBody 230®) and the FITescola® test battery was used. The test battery is divided into three areas, aerobic condition, neuromuscular fitness, and body composition. Flexibility was included in the neuromuscular fitness and was assessed by the seat and reach test (assessing the flexibility of the lower limbs). Three categories were created according to the performance of each student (low flexibility, healthy / normal flexibility, and athletic / high flexibility). The categorization was done by age and according to the FITescola® guidelines. The application of all instruments took place at the same moment of evaluation, during a physical education class. Of a total of 1907 children whose caretakers freely signed the informed consent, 1491

(78.2%) agreed to participate in the study, that included boys and girls aged 9 to 19 years.

Statistical analysis

Descriptive statistics was used to characterize the study sample. Normality of the data was tested, and Mann–Whitney U-test was used to estimate differences in the studied variables between the two groups (gender), and multinomial logistic regression was used to calculate the odds ratio for body composition and flexibility. The statistical significance was set as α=0.05. IBM SPSS Statistic version 26 was used.

RESULTS AND DISCUSSION

In the analysis, significant differences were observed regarding all variables between genders, except for age (p=0.261). Results shown in table 5.1.
To calculate the Odds Ratio (OR), a multinomial logistic regression was performed considering flexibility as the dependent variable (3 categories: low flexibility profile - LFP, normal flexibility profile – NFP, and athletic flexibility profile - AFP) and the remaining variables as independent variables. The reference category is the normal flexibility profile.

Table 5.1. Sample characterization by gender.

	Female			**Male**			**p.value**
	N	Mean	SD	N	Mean	SD	
Age	729	13.97	2.432	762	13.84	2.391	0.261
Flexibility	711	26.22	9.358	750	21.68	8.513	**0.000**
Body Fat Mass	725	16.88	8.362	755	10.76	6.952	**0.000**
Fat Free Mass	725	38.02	6.785	755	46.23	12.43	**0.000**
Skeletal Muscle Mass	725	20.50	4.066	755	25.57	7.545	**0.000**
Body Mass Index	725	21.89	4.217	755	20.91	3.645	**0.000**
Percent Body Fat	725	29.31	8.061	755	18.46	8.807	**0.000**
Basal Metabolic Rate	725	1191	146.5	755	1368	268.3	**0.000**
Waist-Hip Ratio	725	0.87	0.064	755	0.81	0.059	**0.000**

Mann–Whitney U-test: (level of significance 95%)

Through the observation of the sample characterization data, we can see that there are significant differences between genders in the studied variables, but this difference does not exist in the age variable.

Table 5.2. Distribution of the subjects by group for the studied variables.

	Female			Male		
	Low	Normal	High	Low	Normal	High
Flexibility	54.4%	26.9%	18.7%	45.9%	42.3%	11.9%
Body Fat Mass	11.3%	51.2%	37.5%	32.5%	40.9%	26.6%
Fat Free Mass	14.8%	65.9%	19.3%	16.7%	74.0%	9.3%
Skeletal Muscle Mass	34.8%	58.6%	6.6%	34.0%	58.0%	7.9%
Body Mass Index	9.4%	62.2%	28.4%	16.7%	66.0%	17.4%
Percent Body Fat	4.4%	35.2%	60.4%	15.6%	48.9%	35.5%
Basal Metabolic Rate	46.6%	51.6%	1.8%	24.9%	71.8%	3.3%
Waist-Hip Ratio	0.3%	38.3%	61.4%	48.1%	43.2%	8.7%

When comparing the two genders in relation to the percentage in the variables in the study (except age), dividing them into three groups according to the reference values obtained by the bioimpedance system (low profile, normal profile and high profile), we can see that there are also differences between genders (table 5.2).

These gender differences are evident, for example, in individuals with normal flexibility, where the male gender has a higher percentage of individuals with normal flexibility (42.3%) compared to the female gender (26.9%). The male gender also has a higher percentage (32.5% - about three times more) than the female gender (11.3%) in the low-profile group of body fat mass.

At Percent Body Fat this difference is more pronounced in the high-profile group of the female gender (60.4%) compared to the male gender (35.5%). This relationship is also evident in the waist-hip ratio, in which the female gender has a higher percentage (61.4%) compared to the male gender (8.7%) in the high-profile group.

Table 5.3. Logistic regression with flexibility and body composition. Considering normal flexibility as reference.

	Low flexibility profile				Athletic flexibility profile			
	Odds Ratio	95% CI		Sig.	Odds Ratio	95% CI		Sig.
		Lower Bound	Upper Bound			Lower Bound	Upper Bound	
Intercept				**0.000**				**0.000**
Body Fat Mass	1.028	0.729	1.449	0.876	1.054	0.657	1.692	0.827
Fat Free Mass	0.898	0.643	1.254	0.527	1.534	0.975	2.414	0.064
Skel. Musc. Mass	**0.610**	0.449	0.828	**0.002**	0.848	0.564	1.277	0.431
Body Mass Index	0.718	0.496	1.039	0.079	0.935	0.557	1.569	0.799
Percent Body Fat	1.033	0.749	1.426	0.842	1.034	0.667	1.603	0.882
Basal Met. Rate	**0.665**	0.445	0.995	**0.047**	1.416	0.826	2.427	0.205
Waist-Hip Ratio	**1.440**	1.176	1.764	**0.000**	**1.475**	1.111	1.960	**0.007**
Age	**0.819**	0.774	0.867	**0.000**	**1.127**	1.038	1.223	**0.004**

Note: R^2 = .08 (McFadden), .14 (Cox & Snell), .17 (Nagelkerke). Model $\chi^2(1)$ = 226,945, p < .00. * p < .01.

By analysing the data, in table 5.3, we can observe that, an increase in skeletal muscle mass (SMM) reduced the probability by 39% (OR: 0.610; CI: 0.449-0.828) of belonging to the LFP, comparatively to be in the NFP.

The same is observed with the increase of basal metabolic rate (BMR), where we can notice that an increase in this variable reduces the probability to be in the LFP, comparatively to be in the reference category.

The waist-hip ratio (WHR) showed a positive relationship in both groups, where increases in WHR increase the probability of belonging to the LFP and AFP when compared to the NFP.

The probability of belonging to the LFP is lower with increasing age (18%; OR: 0.819; CI: 0.774-1.867), however, at older ages the probability of belonging to the AFP increases by about 13% when compared to the reference category (OR: 1.127; CI: 1,038-1.223).

After analysing the variables together, we carry out the evaluation separately by gender.

Table 5.4. Logistic regression with flexibility and body composition. Data separated between genders: Female.

	Low flexibility profile				Athletic flexibility profile			
	Odds Ratio	95% CI		Sig.	Odds Ratio	95% CI		Sig.
		Lower Bound	Upper Bound			Lower Bound	Upper Bound	
Intercept				**0.004**				**0.000**
Body Fat Mass	**1.883**	1.055	3.361	**0.032**	1.399	0.660	2.967	0.381
Fat Free Mass	0.674	0.428	1.062	0.089	1.010	0.568	1.797	0.973
Skel. Musc. Mass	0.777	0.504	1.198	0.254	1.010	0.587	1.738	0.971
Body Mass Index	**0.467**	0.256	0.853	**0.013**	0.752	0.344	1.644	0.475
Percent Body Fat	0.924	0.561	1.521	0.755	1.136	0.614	2.103	0.685
Basal Met. Rate	0.721	0.386	1.348	0.306	1.689	0.755	3.776	0.202
Waist-Hip Ratio	1.119	0.704	1.778	0.633	0.931	0.516	1.680	0.813
Age	0.947	0.871	1.030	0.206	**1.269**	1.134	1.420	**0.000**

Note: R2 = .07 (McFadden), .13 (Cox & Snell), .15 (Nagelkerke). Model $\chi 2(1) = 99{,}611$, $p < .00$. * $p < .01$.

In the female gender, the increase in body fat mass (BFM) is associated with an increased probability of belonging to the LFP group (88%; OR: 1.883; CI: 1.055-3,361). On the other hand, the higher levels of the body mass index (BMI) increase the probability of belonging to the LFP group by 53% (OR: 0.457; CI: 0.256-0.853). In females, age increases the probability of belonging to the AFP group by 27% (OR: 1.269; CI: 1.134-1.420).

Table 5.5. Logistic regression with flexibility and body composition. Data separated between genders: Male.

	Low flexibility profile				Athletic flexibility profile			
	Odds Ratio	95% CI		Sig.	Odds Ratio	95% CI		Sig.
		Lower Bound	Upper Bound			Lower Bound	Upper Bound	
Intercept				**0.000**				**0.003**
Body Fat Mass	0.698	0.438	1.112	0.131	1.201	0.592	2.435	0.612
Fat Free Mass	1.123	0.665	1.896	0.665	**2.701**	1.190	6.128	**0.017**
Skel. Musc. Mass	**0.533**	0.335	0.848	**0.008**	0.788	0.392	1.584	0.504
Body Mass Index	1.044	0.626	1.741	0.868	1.290	0.604	2.756	0.511
Percent Body Fat	1.071	0.685	1.675	0.764	0.762	0.378	1.536	0.447

Basal Met. Rate	0.758	0.425	1.351	0.347	0.995	0.441	2.242	0.989
Waist-Hip Ratio	1.260	0.879	1.805	0.208	0.743	0.441	1.251	0.264
Age	**0.709**	0.646	0.778	**0.000**	1.105	0.961	1.270	0.161

Note: R2 = .12 (McFadden), .20 (Cox & Snell), .24 (Nagelkerke). Model χ2(1) = 169,10, p < .00. * p < .01.

In males, with the increase in SMM and age variables, the probability of belonging to the LFP group reduced by 47% and 29% respectively (OR: 0.533; CI: 0.335-0.848 and OR: 0.709; CI: 0.646-0.778). when we analyse the probability of belonging to the group of greater flexibility in males, an increase in fat free mass (FFM) increases the probability of belonging to the AFP group when compared to the NFP (OR: 2,701; CI: 1.190-6.128).

CONCLUSION

These data indicate that there are differences in the genres regarding flexibility, and that this is mediated by several factors, including parameters obtained through bio-impedance. In the specific work of flexibility, both in school and in sports in children and adolescents, the use of bio-impedance seems to be an important assessment tool.

REFERENCES

Eler, N. (2018) ‘The Relationship between Body Composition and Physical Fitness Parameters in Children’, International Education Studies. Canadian Center of Science and Education, 11(9), 71. https://doi.org/10.5539/ies.v11n9p71.

Ganley, K. J., Paterno, M. V., Miles, C., Stout, J., Brawner, L., Girolami, G., & Warren, M. (2011). Health-related fitness in children and adolescents. Pediatric physical therapy : the official publication of the Section on Pediatrics of the American *Physical Therapy Association, 23*(3), 208–220. https://doi.org/10.1097/PEP.0b013e318227b3fc.

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., Nieman, D. C., Swain, D. P., & American College of Sports Medicine (2011). American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Medicine and science in sports and exercise, 43*(7), 1334–1359. https://doi.org/10.1249/MSS.0b013e318213fefb.

Haugen, T., Høigaard, R., & Seiler, S. (2014). Normative data of BMI and physical fitness in a Norwegian sample of early adolescents. *Scandinavian journal of public health, 42*(1), 67–73. https://doi.org/10.1177/1403494813504502.

Martim, J. and Simas, M. (2012) 'Flexibilidade e Lesões no Voleibol'. 1. 48-53.

Ruiz, J. R., Castro-Piñero, J., Artero, E. G., Ortega, F. B., Sjöström, M., Suni, J., & Castillo, M. J. (2009). Predictive validity of health-related fitness in youth: a systematic review. *British journal of sports medicine, 43*(12), 909–923. https://doi.org/10.1136/bjsm.2008.056499.

CHAPTER VI

STUDY IV . BACK PAIN, PHYSICAL ACTIVITY HABITS, AND PHYSICAL FITNESS IN CHILDREN AND ADOLESCENTS. A LONGITUDINAL STUDY INCLUDING COVID-19 LOCKDOWN.

Nelson Azevedo[1]*, José Carlos Ribeiro[2] and Leandro Machado[3]

1 CICS, ISAVE, Faculdade de Desporto da Universidade do Porto, 4200-450 Porto, Portugal; nelson.azevedo@docente.isave.pt
2 CIAFEL, ITR, Faculdade de Desporto da Universidade do Porto, 4200-450 Porto, Portugal; jribeiro@fade.up.pt
3 CIFI2D, LABIOMEP, Faculdade de Desporto da Universidade do Porto, 4200-450 Porto, Portugal; lmachado@fade.up.pt
***** *Correspondence: nelson.azevedo@docente.isave.pt*

Current Status: Submitted to Journal of Epidemiology and Global Health.

ABSTRACT

Aim: The first Covid-19 lockdown had a tremendous impact on the entire global society, affecting humans of all ages. Therefore, it is important to examine its impact on back pain, physical activity habits, and physical fitness in children and adolescents.

Subject and Methods: A longitudinal study was conducted with children from schools in northern Portugal, between October and November 2019 and with follow-up between October and November 2020. In both evaluation moments, the same online questionnaire was used to assess the sample in terms of physical activity habits and back pain characterization, while physical fitness was analyzed using the FITescola® test battery. Aerobic condition, body composition, and neuromuscular fitness were part of the test battery.

Results: Between the two assessment times, most participants improved their physical fitness, except for push-ups in children and female gender and curl-ups in adolescents. During this period, most participants kept doing physical activity regularly. The frequency of back pain was higher in females, and the most cited regions were the lumbar and thoracic spine. The most affected region was the thoracic spine in children, and the lumbar spine in adolescents. Increasing physical fitness, especially the neuromuscular condition of the upper body, assessed through push-ups, had a protective effect on the manifestation of back pain in children and adolescents.

Conclusion: During the year span, including the first lockdown, children and adolescents maintained regular physical activity habits and increased most levels of physical fitness. Increased physical fitness had a protective effect on the incidence of back pain.

Keywords: Children; Adolescents; Covid-19; Physical fitness; Back pain.

INTRODUCTION

Back pain is a problem that is becoming more common in today's world, both in adults and younger children (James et al., 2018; Wu et al., 2020). The risk factors associated with the development of back pain are increasingly researched and understood (Balague et al., 1999; Calvo-Muñoz et al., 2018). This understanding allows for the development of more effective prevention strategies for risk factors, helping to improve the quality of life for children and adolescents (Kamper et al., 2016; Nawrocka et al., 2014; Watson et al., 2003). Among the various factors associated with back pain in children and adolescents, sedentarism appears to be one of the most important (Kędra et al., 2021; Vierola et al., 2016).

Recently, the world faced the pandemic associated with Covid-19, and its effects were felt at different levels all across the globe (Haileamlak, 2021; Mallah et al., 2021; Parums, 2021). These effects were felt primarily at the level of health services, as hospital systems and the entire health care system had to be reorganized (Haldane et al., 2021; Haldane & Morgan, 2020; Shroff et al., 2021), which was reflected also in Portugal (Campos et al., 2021; Mallah et al., 2021; Ricoca Peixoto et al., 2020).

After the first confirmed cases, the Portuguese government decided to declare a state of emergency and to restrict all non-essential activities, including schools (Comunicação enviada às escolas sobre suspensão das atividades com alunos nas escolas de 16 de março a 13 de abril, n.d.). This lockdown started in March 2020 with classes held online. In presence classes resumed in June for adolescents from the 11th grade and above, while younger children (under 11th grade) continued to participate in online classes through the end of the school year (Comunicado do Conselho de Ministros de 9 de abril de 2020, n.d.).

During this time, due to the restrictive measures and the fear associated with the virus and its propagation, sports and physical activities were reduced to the essential (de Figueiredo et al., 2021). This condition resulted in a significant increase in sedentary behavior across all age groups, but particularly among children and adolescents (Guo et al., 2021; Ito et al., 2022; Okuyama et al., 2021; Pfefferbaum & Van Horn, 2022). To minimize the lack of scholarly physical activity during the lockdown, several countries, including Portugal, introduced online Physical Education classes (Béghin et al., 2022; Moore et al., 2020; Sunda et al., 2021).

In addition to physical activity, physical fitness is now considered an important health indicator for children and adolescents (Ortega et al., 2008). There is an inverse relationship between sedentary levels and physical fitness in the younger population (Mateo-Orcajada et al., 2022). In Portugal, physical fitness is assessed at the beginning of each school year in Physical Education classes.

This study was developed as a longitudinal study during one school year related to postural changes and the manifestation of back pain in the young population. However, the Covid-19 pandemic has highlighted a risk factor, sedentarism, that is now increasingly important in the manifestation of back pain in adults, children, and adolescents.

Taking advantage of this constraint in the study population, we therefore examined the changes in physical activity habits and changes in physical fitness in children and adolescents resulting from a year span including the Covid-19 restrictions, particularly the first lockdown, and whether these changes were associated with the manifestation of back pain in these populations.

MATERIAL AND METHODS

Study design and participants

A longitudinal study was conducted with children from a school cluster in northern Portugal, in the district of Braga, between October and November 2019 (first assessment time point) and between October and November 2020 (second assessment time point), both at the beginnings of their respective school year.

During this period, the first Covid-19 lockdown took place in Portugal. Schools were closed on March 16, 2020, and students were sent home to continue their classes online. In June, the 11th and 12th-grade students returned for presential classes. On September 14, all students resume presential classes. Physical education classes were maintained online for all children and adolescents until the end of the school year (July 2020), including during the lockdown.

All children and adolescents in the school cluster, and their respective parents or tutors, received a description of the study and written informed consent. The study was explained to physical education teachers and later to parents through exposure interviews. Of a total of 1907 children who received informed consent, 1491 (78%) agreed to participate in the study. Participants who had acute or chronic musculoskeletal injuries that precluded data collection did not participate in the study, even with approved informed consent.

After data collection, only 780 participants fully completed both year assessments and were included in this study (361 female and 419 male). The exclusion criteria from the study included changing schools or finishing their studies, or failing to complete the full assessments, as well as the mentioned acute or chronic musculoskeletal injuries.

The physical fitness battery tests were carried out between October and November in physical education classes by physical education teachers. The online questionnaire was answered at home, during October, and the participants could present their doubts to the teacher.

Children and adolescents aged 9 to 17 years old participated in the study. The classification of children and adolescents was based on the study by Furlanetto et al. (2018) (Furlanetto et al., 2018). The first classification was maintained in the second evaluation time point, although some children became adolescents during this time.

Instruments

In both evaluation moments, an online questionnaire (Google Forms) was used to characterize the sample in terms of their physical activity habits and back pain categorization. In the same questionnaire, the 11-item numerical rating scale (NRS-11) was used to quantify the children's back pain. To facilitate the assessment of self-reported back pain, a graphical scheme combining the NRS-11 and the Faces Pain Scale - Revised was chosen. These two scoring systems proved to be a reliable tool for assessing child- and adolescent- reported pain (Birnie et al., 2019).

The students answered the questionnaire within 4 weeks from the beginning of the school year.

Physical fitness was analyzed using the FITescola® test battery(Henriques-Neto et al., 2020). The test battery includes a series of tests divided into three sections: Aerobic Condition, Body Composition, and Neuromuscular Fitness. Aerobic condition was evaluated by the 20 m shuttle run (20m-SR). Body Composition was evaluated by Body Mass Index (BMI). Neuromuscular Fitness was assessed in three main components: trunk neuromuscular condition, upper body neuromuscular condition, and lower body neuromuscular condition. Trunk neuromuscular condition was assessed using curl-ups. The neuromuscular condition of upper body strength and endurance was evaluated by push-ups. The neuromuscular condition of the lower limbs was evaluated by the long jump (Health-Related Fitness Measures for Youth: Musculoskeletal Fitness - Fitness Measures and Health Outcomes in Youth - NCBI Bookshelf, n.d.). Flexibility was assessed with the sit-and-reach test (SR-T), which is used to assess the flexibility of the lower back and the upper hamstring (Health-Related Fitness Measures for Youth: Musculoskeletal Fitness - Fitness Measures and Health Outcomes in Youth - NCBI Bookshelf, n.d.).

Statistical analysis

Descriptive statistics were used to characterize the sample by gender and age groups, at the two evaluation moments. Normality of the data was tested. The chi-square test was used to estimate the differences between genders, age classes and manifestations of back pain. The Phi correlation coefficient test was used to measure the relationship between two binary variables.

Paired samples t-test was used to assess differences between the means of the anthropometric variables, physical fitness, and pain scores in the two evaluation moments.

Nonparametric tests (McNemar test for dichotomous variables and Wilcoxon Signed Ranks Test) were used to assess differences between physical activity habits, physical fitness, and back pain characterization.

Binary logistic regression was used to calculate the odds ratio (OR) for manifestation of back pain, for habits of regular physical activity and for physical fitness between the two assessment time points. For this analysis, the OR was calculated in terms of nominal variables with three categories each; has not changed (reference), increased, and decreased.

Statistical significance was set at α=0.05. The statistical software IBM SPSS (IBMCorp, Armonk, NY, USA, version 26) was used.

RESULTS

Considering the characterization of the sample, Table 6.1 shows a natural increase in the average mass and height of the participants. Analysis Regarding physical fitness, Table 6.1 shows that the average values of physical fitness improved at all assessed levels, except for the push-ups in the female gender, which decreased in the second assessment time point.

The results also show that the male gender has higher mean scores than the female gender in all physical fitness assessments, except for SR-T and BMI, where the female gender has higher scores.

The average back pain scores reported by the participants display a slight increase from the first to the second assessment, both in females and in males.

When analyzing the data comparing children and adolescents at the two assessment moments, a natural increase in anthropometric data was observed in both children and adolescents. We recall that the classification as “child” did not change between the two evaluation moments, although some children had become adolescents by the second assessment.

Considering the physical fitness data, the adolescents have higher scores on all assessed parameters. However, when we evaluate the change between the two assessment moments, both groups increase the mean values of the 20m-SR, Long jump, SR-T and BMI. For the curl-up, the children increase their mean value, while the adolescents decrease it. For the push-up, the reverse is observed: the children decrease while the adolescents increase their respective values.

The intensity of referred pain increased in both groups between the two evaluation time points, although the increase was more pronounced in the children.

Table 6.1 Sample characterization by gender at the two evaluation moments.

	First assessment		Second assessment		First assessment		Second assessment	
	Female (361)	Male (419)	Female (361)	Male (419)	Children* (180)	Adolescents* (600)	Children* (180)	Adolescents* (600)
Continuous variables	Mean/ SD	Mean/ SD	Mean/ SD	Mean/ SD	Mean/ SD	Mean/ SD	Mean/ SD	Mean/ SD
Anthropometric data								
Age (years)	13.39/ 2.10	13. 37/ 2.01	14.39/ 2.09	14. 34/ 2.03	10.43/ 0.57	14.26/ 1.40	11.39/ 0.56	15.26/ 1.40
Mass (kg)	52.45/ 11.90	55.34/ 15.43	55.42/ 11.96	60.31/ 15.21	41.35/ 9.95	57.80/ 12.73	46.34/ 11.41	61.56/ 12.75
Height (cm)	156.84/ 8.70	162.72/ 13.61	159.99/ 7.12	168.50/ 11.84	146.57/ 7.51	164.03/ 9.93	153.78/ 8.08	167.79/ 9.32
Physical fitness								
20m-SR (nº)	32.59/ 12.79	58.42/ 25.47	33.07/ 12.51	60.34/ 24.49	30.22/ 13.89	51.34/ 24.63	32.53/ 15.83	52.27/ 24.25
Curl-up (nº)	35.17/ 18.75	48.56/ 23.26	36.92/ 17.05	49.75/ 20.32	25.07/ 15.65	47.55/ 21.38	34.53/ 20.56	46.60/ 18.88
Push-up (nº)	11.22/ 6.85	16.63/ 9.11	10.43/ 6.06	17.00/ 8.61	11.67/ 7.79	14.86/ 8.67	9.77/ 6.60	15.22/ 8.24
Long jump (cm)	135.77/ 23.13	167.75/ 33.50	142.31/ 22.51	180.75/ 33.45	124.28/ 21.14	161.55/ 31.32	138.16/ 24.63	170.40/ 33.80
SR-T (cm)	26.42/ 9.00	21.08/ 8.14	28.39/ 8.64	22.41/ 8.34	18.25/ 6.76	25.14/ 8.92	20.60/ 7.69	26.55/ 8.90
BMI (kg/m^2)	21.17/ 3.81	20.54/ 3.59	21.55/ 4.02	21.02/ 3.87	18.91/ 3.23	21.40/ 3.64	19.43/ 3.65	21.82/ 3.87
Pain assessment								
NRS-11	4.84/ 1.77	4.44/ 1.90	5.06/ 1.96	4.95/ 1.69	4.00/ 1.75	4.78/ 1.83	5.30/ 1.96	4.93/ 1.81

* Group classification is the same in both evaluation moments, although some children had become adolescents by the second assessment.

A Paired samples t-test was performed to compare the mean values of the continuous variables between the two assessment times for the full sample (Table 6.2). Based on the data, there were significant differences in anthropometric variables reflecting the normal growth of the participants. In the physical fitness scores, there was a significant increase in all parameters assessed, except for push-ups, where the average score decreased among participants, but was not significant (p = 0.502).

There were also no significant differences in the manifestation of pain scores (NRS-11) between the two assessment time points, despite the slight increase.

Table 6.2 Paired samples t-test comparing the year span between evaluations, considering the full sample.

	Mean difference	Std. Deviation	t	df	p-value*
Anthropometric data					
Age (yrs)	0.99	0.10	274.18	779	**0.000**
Mass (kg)	4.04	5.23	21.61	779	**<0.001**
Height (cm)	4.56	4.02	31.71	779	**<0.001**
Physical fitness					
20m-SR (nº)	1.25	11.68	3.00	779	**0.003**
Curl-up (nº)	1.45	17.43	2.32	779	**0.021**
Push-up (nº)	-0.17	7.04	-0.67	779	0.502
Long jump (cm)	10.01	18.44	15.16	779	**<0.001**
SR-T (cm)	1.62	5.23	8.67	779	**<0.001**
BMI	0.44	1.78	6.86	779	**<0.001**
Pain assessment					
NRS-11	0.10	2.13	0.56	156	0.575

* Paired samples t-test comparing the two evaluation moments (Moment 2 – Moment 1) (level of significance 95%).

The manifestation of back pain between the two evaluating moments (Table 6.3), shows differences between genders (p < 0.001), and that most subjects do not had back pain (66.9%) in the course of that year. The prevalence of back pain was higher in females compared to males (42.9% vs. 24.6%). The majority reported back pain in the previous month (62.0%), and gender differences were not significant. The frequency of manifestation of back pain shows significant differences between genders (p = 0.006). In females, manifestation of back pain “Once a week” had the highest percentage (23.2%); in males, manifestation of back pain “Once per month” was the most referred (26.2%). The lumbar spine, followed by the thoracic spine, were the most frequently mentioned by both genders, with no differences between genders (p = 0.119). Despite the reference to back pain, most respondents of both genders did not report any functional limitation due to this pain (73.3%).

Table 6.3. Differences by Gender in the manifestations of back pain between the two evaluation moments.

		Female		**Male**		**Total (F+M)**		***p*-value**
		N	%	N	%	N	%	(F/M)
Presence of back pain since the last evaluation								
	No	206	57.1	316	75.4	522	66.9	**<0.001***
	Yes	155	42.9	103	24.6	258	33.1	
Total		361	100	419	100	780	100	
How long has it been since you had this back pain since the last evaluation?								
	From a day to a month	99	63.9	61	59.2	160	62.0	
	From 1 to 3 months	26	16.8	24	23.3	50	19.4	
	From 4 to 6 months	12	7.7	12	11.7	24	9.3	0.185**
	From 7 to 9 months	18	11.6	6	5.8	24	9.3	
	From 10 to 12 months	0	0	0	0	0	0	
Total		155	100	103	100	258	100	
How often did back pain occur?								
	Just one time	34	21.9	25	24.3	59	22.9	
	Once per month	26	16.8	27	26.2	53	20.6	
	Once a week	36	23.2	19	18.4	55	21.3	
	2 to 3 times a week	34	21.9	13	12.6	47	18.2	**0.006****
	4 times or more per week	17	11.0	4	3.9	21	8.1	
	I don't know how to answer.	8	5.2	15	14.6	23	8.9	
Total		155	100	103	100	258	100	
What is/was the region of your back pain?								
	Cervical	35	22.6	13	12.6	48	18.6	
	Thoracic	45	29.0	41	39.8	86	33.3	
	Lumbar	71	45.8	45	43.7	116	45.0	0.119**
	Pelvis	4	2.6	4	3.9	8	3.1	
Total		155	100	103	100	258	100	
This back pain prevents or prevented you from activities from your normal life?								
	No	113	72.9	76	73.8	189	73.3	
	Yes	42	27.1	27	26.2	69	26.7	0.875*
Total		155	100	103	100	258	100	

* Phi correlation coefficient test: (level of significance 95%)

**Chi-Square Test: (level of significance 95%)

When regarding the presence of back pain data separated by age group, children and adolescents (Table 6.4), it is worth noticing the lack of differences between the two groups and that most of the subjects from both groups did not report back pain during the year span including the lockdown (children: 65.0%, adolescents: 67.5%). Of those who did experience back pain, the majority reported having pain in the previous month. There were significant differences between children and adolescents in the frequency of occurrence of back pain ($p = 0.042$). One found a higher percentage of children reporting that the pain occurred only once, while adolescents reported other frequencies as the most common. The region in which children most frequently reported back pain was the thoracic region (49.2%), whereas adolescents most frequently mentioned the lumbar region (49.7%). The back pain reported by children and adolescents did not prevent most of them from performing normal life activities, although the percentage of impairment was higher in children than in adolescents (38.1% vs 23.1%, representing 13.3% and 7.5% of their total age class, respectively).

Table 6.4. Differences by Age Class in the manifestations of back pain during the one year span.

	Children		Adolescents		Total (C+A)		p-value
	N	%	N	%	N	%	(C/A)
Presence of back pain since the last evaluation							
No	117	65.0	405	67.5	522	66.9	0.532*
Yes	63	35.0	195	32.5	258	33.1	
Total	180	100	600	100	780	100	
How long has it been since you had this back pain since the last evaluation?							
From a day to a month	40	63.5	120	61.5	160	62.0	0.885**
From 1 to 3 months	11	17.5	39	20.0	50	19.4	
From 4 to 6 months	7	11.1	17	8.7	24	9.3	
From 7 to 9 months	5	7.9	19	9.8	24	9.3	
From 10 to 12 months	0	0	0	0	0	0	
Total	63	100	195	100	258	100	
How often did back pain occur?							
Just one time	21	33.3	38	19.5	59	23.0	**0.042****
Once per month	15	23.8	38	19.5	53	20.5	
Once a week	15	23.8	40	20.5	55	21.3	
2 to 3 times a week	6	9.6	41	21.0	47	18.2	
4 times or more per week	4	6.3	17	8.7	21	8.1	
I don't know how to answer.	2	3.2	21	10.8	23	8.9	
Total	63	100	195	100	258	100	
What is/was the region of your back pain?							
Cervical	12	19.0	36	18.5	48	18.6	**0.012****
Thoracic	31	49.2	55	28.2	86	33.3	
Lumbar	19	30.2	97	49.7	116	45.0	
Pelvis	1	1.6	7	3.6	8	3.1	
Total	63	100	195	100	258	100	
This back pain prevents or prevented you from activities from your normal life?							
No	39	61.9	150	76.9	189	73.3	**0.019***
Yes	24	38.1	45	23.1	69	26.7	
Total	63	100	195	100	258	100	

* Phi correlation coefficient test: (level of significance 95%)

**Chi-Square Test: (level of significance 95%)

Analysis of variables related to physical activity habits, pain, and physical fitness in the year span between evaluations (Table 6.5) shows that most children and adolescents have not changed the manifestation of back pain during that year

(60.8%), with 26.3% no longer experiencing back pain, while 12.9% reported back pain for the first time in this period.

Of those who reported back pain in both assessments, it persisted at the same intensity in only 20.4% of cases. The percentage of children and adolescents in whom the intensity of back pain increased (40.1%) was slightly higher than the percentage in whom it decreased (39.5%). However, these differences were not significant ($p = 0.459$).

When analysing changes related to physical activity habits, we found that most participants maintained regular physical activity (55.5%) and 13.5% started participating. Only 11.2% abandoned participation in regular physical activity, while 19.7% remained sedentary in that year span.

The number of days and hours dedicated to physical activity was also maintained by most of the participants, and it can be observed that the percentage of those who reduced the physical activity time was higher than those who increased it.

For physical fitness scores, most participants improved their physical fitness on all parameters compared to participants who decreased physical fitness scores. These differences were statistically significant except for push-ups ($p = 0.965$).

The percentage of participants who increased their BMI was also significantly higher compared to those who decreased it.

Table 6.5. Differences between the two evaluation moments related to the physical activity habits, pain, and physical fitness variables.

	Decreased		Not changed		Increased		Total	p-value
Variables	N	%	N	%	N	%	N	
Pain assessment								
Presence of back pain++	205	26.3	474 (157 Y/Y) (317 N/N)	60.8 (20.1) (40.6)	101	12.9	780	**<0.001***
NRS-11 (pain level)	61	39.5	32	20.4	64	40.1	157	0.459**
Physical activity habits								
Do you practice some physical activity regularly++	88	11.2	587 (433 Y/Y) (154 N/N)	75.3 (55.5) (19.7)	105	13.5	780	0.249*
How many days do you practice this physical activity per week.	159	36.7	247	57.0	27	6.3	433	**<0.001****
How many hours do you practice this physical activity per day.	150	34.6	231	53.4	52	12.0	433	**<0.001****
Physical fitness								
20m-SR	320	41.0	95	12.2	365	46.8	780	**0.008****
Curl-up	303	38.8	108	13.8	369	47.3	780	**0.034****
Push-up	314	40.3	130	16.6	336	43.1	780	0.965**
Long jump	177	22.7	96	12.3	507	65.0	780	**<0.001****
SR-T	228	29.2	116	14.9	436	55.9	780	**<0.001****
BMI	267	34.2	21	2.7	492	63.1	780	**<0.001****

++ Decreased: changed from "Yes" to "No"; Increased: changed from "No" to "Yes".

* McNemar Test (level of significance 95%)

** Wilcoxon Signed Ranks Test (level of significance 95%)

To obtain the odds-ratio (OR) of manifestation of back pain and its relationship with the habits of regular physical activity practice and physical fitness, binary logistic regression was used (Table 6.6). From the results, the only statistically significant change was the increase in push-ups, associated with a protective effect (decrease) on the manifestation of back pain in 45.5% (OR: 0.545; CI: 0.329-0.901).

Table 6.6. Binary logistic regression for back pain and its relationship with the physical activity habits and physical fitness.

	N	Odds Ratio	95% CI		p-value
			Lower Bound	Upper Bound	
Physical activity habit	780				
Do you practice some physical activity regularly (*Reference: remained sedentary*)	154				
Remained active	433	0.848	0.570	1.263	0.418
Decreased	88	1.231	0.710	2.135	0.459
Increased	105	1.177	0.695	1.994	0.545
Physical fitness	780				
20m-SR (*Reference: has not changed*)	95				
Increased	365	1.125	0.614	2.062	0.703
Decreased	320	1.198	0.659	2.180	0.554
Curl-up (*Reference: has not changed*)	108				
Increased	369	1.365	0.753	2.472	0.305
Decreased	303	1.498	0.827	2.716	0.183
Push-up (*Reference: has not changed*)	130				
Increased	336	0.551	0.333	0.911	**0.020**
Decreased	314	0.852	0.521	1.393	0.523
Long jump (*Reference: has not changed*)	96				
Increased	507	0.808	0.428	1.525	0.511
Decreased	177	0.948	0.481	1.868	0.877
SR-T (*Reference: has not changed*)	116				
Increased	436	1.022	0.591	1.766	0.938
Decreased	228	0.780	0.440	1.382	0.395
BMI (*Reference: has not changed)*	21				
Increased	492	0.721	0.286	1.819	0.489
Decreased	267	0.790	0.309	2.021	0.623

DISCUSSION

Aim of the study

The aim of the work was to perform a longitudinal study of the prevalence of back pain and the precipitating factors, namely postural patterns, physical fitness, and physical activity habits. However, the Covid-19 pandemic enabled us to evaluate the impact on children and adolescents of a lockdown lasting several months, both in terms of manifestation of back pain and in terms of physical fitness and physical activity habits. The pandemic due to Covid-19 had many consequences, including for the education system. These effects are also directly reflected in the daily school life of the youngest, whether in the teaching methodology, with lessons taking place in an online format, or in the interaction of the children and adolescents with the school itself. Children's sedentary lifestyles are a growing problem, and school is often a means for children to develop their motor and physical skills. With this study, we aimed to understand the impact of forced absence from school on children's physical activity habits and motor skills.

Anthropometric data in the two evaluation moments

Considering the separation between children and adolescents, the results obtained on anthropometric data followed the natural course between the two evaluation times: age, mass and height increased over that year span, which were also reflected in BMI. The difference in growth, expressed in height but also in mass gain, was more pronounced in children than in adolescents during this period. This result reflects normal growth at this stage of development (de Onis et al., 2007).

Analysis of this trend by gender showed that the mass and height of boys increased more than those of girls, which is in accordance with other studies (Zheng et al., 2013). Girls' BMI was higher than boys' at both assessment times, which is consistent with Sweeting and West's (2002) study (Sweeting & West, 2002).

Physical fitness in the two evaluation moments

Between the two evaluation time points, children and adolescents of both genders increased their physical fitness, except for push-ups in children and female gender and curl-ups in the adolescent group. This goes against some studies in the literature: a study conducted in France, including the period of the first lockdown due to Covid-19, found that children and adolescents of both genders reduced their levels of physical fitness, with the exception of cardiorespiratory fitness in males and flexibility in both males and females (Béghin et al., 2022). Several studies conducted in other countries confirmed this trend (Jarnig et al., 2022; López-Bueno et al., 2021; Sunda et al., 2021; Tsoukos & Bogdanis, 2022), and showed that females and males at school age had significant decreases in physical fitness performance after successive lockdowns due to coronavirus disease.

Comparing our results with previous studies, an opposite general trend can be observed. Therefore, we may infer that the first lockdown had different effects in different countries, irrespective of having implemented online Physical Education classes, or not.

Change in physical activity habits at the two evaluation moments.

With lockdown, most elements of the sample studied did not stop engaging in physical activity, even with limitations on traveling. From these data, it appears that children and adolescents have developed strategies to continue physical activity, namely outdoor activities that avoid crowds, being the indication of limitation of clusters of people the responsibility of the Portuguese government to mitigate the impact of the pandemic in 2020 (Resolução Do Conselho de Ministros n.o 43-B/2020, de 12 de Junho | DRE, n.d.). The schools also created conditions for maintaining physical activity, namely online physical education classes. These strategies were important to maintain physical activity and avoid the consequences of a sedentary lifestyle in the young population. These data are consistent with a report from UNICEF (Innocenti, n.d.), which highlights the resilience of children and adolescents with positive coping strategies (e.g., physical activity and leisure time), more time for self or family, and more flexible schedules that contributed to children's and adolescents' well-being during the Covid-19 pandemic. A study conducted on Spanish children and adolescents also showed this resilience during lockdown

(Ajanovic et al., 2021). Despite the data of our study showing positive strategies related to physical activity in children and adolescents, these results are in contrast with the results of other studies showing increased levels of sedentary lifestyle in the younger population during confinement, with negative effects on the level of physical activity, but also on mental health (Guo et al., 2021; Ito et al., 2022; Okuyama et al., 2021; Pfefferbaum & Van Horn, 2022).

Back pain during the two evaluation moments.

The female gender had a higher percentage of back pain manifestations than the male gender at both assessment time points. The higher frequency of back pain manifestation in females, adds support to the fact that this manifestation was more likely to occur in the female gender (Hoy et al., 2012; Minghelli et al., 2014; Rossi et al., 2016). The reason why females have a higher frequency and higher intensity of back pain than males is still not entirely clear, but some studies report that puberty and the onset of adolescence may be an important determining factor for the greater manifestation of back pain (Masiero et al., 2008; Schmitz et al., 2013). A possible reason for this difference between the genders, it could be a decrease in the pain threshold in the female gender (Schmitz et al., 2013).

For the students reporting having had back pain between both assessment time points, most of them report experienced it in the month before the second assessment. The lumbar and thoracic spine had the highest prevalence of back pain. These data are consistent with other studies (Briggs et al., 2009; Poussa et al., 2005). Nevertheless, this pain did not limit daily functionality of the students. These data are in contrast with the values of impairment caused by back pain in adults (Manchikanti et al., n.d.; Rubin, 2007). However, this risk increases with age, and the manifestation of back pain in childhood and adolescence increases the risk of developing back pain in adulthood (Frosch et al., 2022; Hestbaek & Cassidy, 2013). Adolescents' prevalence data for back pain in the current study are close to adult prevalence data (Hoy et al., 2012).

Still analyzing the data by age class shows significant differences on the manifestation of back pain, namely in the frequency of occurrence and its location. Children mostly refer to the manifestation of pain only once, while adolescents mention several occurrences. Considering the location of pain, the thoracic spine was the most cited by children, and the lumbar spine by adolescents. These data may be related to long periods of electronic device use, as some studies report periods of more than 5 hours per day with electronic devices during lockdown (Ajanovic et al., 2021). Watching TV more than 2 hours per day in children and adolescents is associated with an increased risk of back pain (Szita et al., 2018). There are also studies showing the relationship between posture and the manifestation of back pain (Azevedo et al., 2022; Minghelli, 2020; Trigueiro et al., 2013).

Although most children and adolescents in the study reported that back pain did not prevent them from performing their normal daily activities, there were significant differences between the two groups, with children having more impaired function. Although back pain is a complex and multifactorial condition (Frosch et al., 2022), particularly for children and adolescents (Lynch et al., 2006), studies have shown greater functional limitations with increasing age, especially for the female gender (Roth-Isigkeit et al., 2005). Pain intensity increased between the first and second evaluation moments in both genders, as well as in children and adolescents.

Physical fitness also proved to be a (protective) risk predictor for back pain, particularly the push-ups, where those who increased their physical fitness in this component during the two evaluation time points had their odds ratio for back pain decreased. Studies demonstrated the relationship between the level of physical fitness and the manifestation of back pain, especially the relationship with cardiorespiratory fitness (Galmés-Panadés & Vidal-Conti, 2022), and the association with low isometric muscle endurance in the back extensors(Bo Andersen et al., 2006).

The change in the practice of regular physical activity, that is, those who stopped or started it, was not reflected in the manifestation of back pain during the evaluation period. A recent systematic review shows moderate evidence for a relationship between back pain and regular physical activity in children and adolescents, especially those who have very high or very low levels of regular physical activity (Kędra et al., 2021). Our findings highlight the importance of a joint analysis of physical activity habits and physical fitness to better understand back pain in the younger population.

With this study we provide a new perspective on the impact of lockdown on children and adolescents, both in terms of physical fitness and the occurrence of back pain.

Limitations

This study represents only one geographical region of Portugal, and it would be important to verify if there are differences between regions and differences between the urban population and that of more rural areas.

CONCLUSION

During the year comprising the first lockdown, children and adolescents maintained their regular physical activity habits and increased most levels of physical fitness. Increased physical fitness has been shown to have a protective effect on the incidence of back pain. The change in the practice of regular physical activity was not reflected in the manifestation of back pain.

Acknowledgments

We would like to thank the Padre Benjamim Salgado school group, as well as its general director and the physical education group, especially Paulo Pereira and Flávio Salgado. Their support was crucial for the implementation of the study. We would also like to thank the children and adolescents, as well as their parents and legal representatives, for their willingness to participate in the study. We would also like to thank the staff of Nelson Azevedo Terapias GIobais Clinic - for their assistance with data collection.

Funding

This research received no external funding.

Conflicts of interest/Competing interests

The authors declare that they have no competing interests.

Ethics approval

This study was approved by the Ethics Committee of FADEUP - University of Porto (CEFADE 50, 2019) and conducted according to the guidelines of the Declaration of Helsinki. Permission to conduct the study in schools was granted by their director, allowing data collection and ensuring all legal requirements and confidentiality for all participants.

Consent to participate

Written informed consent was obtained from parents or legal guardians of all study participants.

Availability of data and material

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

Nelson Azevedo participated in the design of the study, contributed to data collection, data analysis and interpretation of results; Leandro Machado participated in the design of the study and contributed to data analysis and interpretation of results; José Carlos Ribeiro contributed to data analysis and interpretation of results. All authors contributed to the manuscript writing. All authors have read and approved the final version of the manuscript and agree with the order of presentation of the authors.

REFERENCES

Ajanovic, S., Garrido-Aguirre, J., Baro, B., Balanza, N., Varo, R., Millat-Martínez, P., Arias, S., Fonollosa, J., Perera-Lluna, A., Jordan, I., Muñoz-Almagro, C., Bonet-Carne, E., Crosas-Soler, A., Via, E., Nafria, B., García-García, J. J., & Bassat, Q. (2021). How Did the COVID-19 Lockdown Affect Children and Adolescent's Well-Being: Spanish Parents, Children, and Adolescents Respond. *Frontiers in Public Health, 9*, 746052. https://doi.org/10.3389/fpubh.2021.746052.

Azevedo, N., Ribeiro, J. C., & Machado, L. (2022). Balance and Posture in Children and Adolescents: A Cross-Sectional Study. *Sensors (Basel, Switzerland), 22*(13), 4973. https://doi.org/10.3390/s22134973.

Balagué, F., Troussier, B., & Salminen, J. J. (1999). Non-specific low back pain in children and adolescents: risk factors. *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 8*(6), 429–438. https://doi.org/10.1007/s005860050201.

Béghin, L., Thivel, D., Baudelet, J.-B., Deschamps, T., Ovigneur, H., & Vanhelst, J. (2022). Change in physical fitness due to the COVID-19 pandemic lockdown in French adolescents: A comparison between two independent large samples from Diagnoform battery. *European Journal of Pediatrics, 181*(11), 3955–3963. https://doi.org/10.1007/s00431-022-04610-9.

Birnie, K. A., Hundert, A. S., Lalloo, C., Nguyen, C., & Stinson, J. N. (2019). Recommendations for selection of self-report pain intensity measures in children and adolescents: A systematic review and quality assessment of measurement properties. *Pain, 160*(1), 5–18. https://doi.org/10.1097/j.pain.0000000000001377.

Bo Andersen, L., Wedderkopp, N., & Leboeuf-Yde, C. (2006). Association between back pain and physical fitness in adolescents. *Spine, 31*(15), 1740–1744. https://doi.org/10.1097/01.brs.0000224186.68017.e0.

Briggs, A. M., Smith, A. J., Straker, L. M., & Bragge, P. (2009). Thoracic spine pain in the general population: Prevalence, incidence and associated factors in children, adolescents and adults. A systematic review. *BMC Musculoskeletal Disorders, 10*(1). https://doi.org/10.1186/1471-2474-10-77.

Calvo-Muñoz, I., Kovacs, F. M., Roqué, M., Fernández, I. G., & Calvo, J. S. (2018). Risk Factors for Low Back Pain in Childhood and Adolescence: A Systematic Review. *Clinical Journal of Pain, 34*(5), 468–484. https://doi.org/10.1097/AJP.0000000000000558.

Campos, R., Pinto, V., Alves, D., Rosa, C. P., & Pereira, H. (2021). Impact of COVID-19 on the Mental Health of Medical Students in Portugal. *Journal of Personalized Medicine, 11*(10), 986. https://doi.org/10.3390/jpm11100986.

Comunicação enviada às escolas sobre suspensão das atividades com alunos nas escolas de 16 de março a 13 de abril. (n.d.). Retrieved 23 October 2022, from https://www.portugal.gov.pt/pt/gc22/comunicacao/documento?i=comunicacao-enviada-as-escolas-sobre-suspensao-das-atividades-com-alunos-nas-escolas-de-16-de-marco-a-13-de-abril.

Comunicado do Conselho de Ministros de 9 de abril de 2020. (n.d.). Retrieved 23 October 2022, from https://www.portugal.gov.pt/pt/gc22/governo/comunicado-de-conselho-de-ministros?i=340.

de Figueiredo, C. S., Sandre, P. C., Portugal, L. C. L., Mázala-de-Oliveira, T., da Silva Chagas, L., Raony, Í., Ferreira, E. S., Giestal-de-Araujo, E., Dos Santos, A. A., & Bomfim, P. O.-S. (2021). COVID-19 pandemic impact on children and adolescents' mental health: Biological, environmental, and social factors. *Progress in Neuro-Psychopharmacology & Biological Psychiatry, 106*, 110171. https://doi.org/10.1016/j.pnpbp.2020.110171.

de Onis, M., Onyango, A. W., Borghi, E., Siyam, A., Nishida, C., & Siekmann, J. (2007). Development of a WHO growth reference for school-aged children and adolescents. *Bulletin of the World Health Organization, 85*(9), 660–667. https://doi.org/10.2471/blt.07.043497.

Frosch, M., Mauritz, M. D., Bielack, S., Blödt, S., Dirksen, U., Dobe, M., Geiger, F., Häfner, R., Höfel, L., Hübner-Möhler, B., von Kalle, T., Lawrenz, B., Leutner, A., Mecher, F., Mladenov, K., Norda, H., Stahlschmidt, L., Steinborn, M., Stücker, R., … Zernikow, B. (2022). Etiology, Risk Factors, and Diagnosis of Back Pain in Children and Adolescents: Evidence- and Consensus-Based Interdisciplinary Recommendations. *Children, 9*(2), 192. https://doi.org/10.3390/children9020192.

Furlanetto, T. S., Sedrez, J. A., Candotti, C. T., & Loss, J. F. (2018). Reference values for Cobb angles when evaluating the spine in the sagittal plane: A systematic review with meta-analysis. *Motricidade, 14*(2–3), Article 2–3. https://doi.org/10.6063/motricidade.10890.

Galmés-Panadés, A. M., & Vidal-Conti, J. (2022). Association between Physical Fitness and Low Back Pain: The Pepe Cross-Sectional Study. *Children, 9*(9), Article 9. https://doi.org/10.3390/children9091350

Guo, Y.-F., Liao, M.-Q., Cai, W.-L., Yu, X.-X., Li, S.-N., Ke, X.-Y., Tan, S.-X., Luo, Z.-Y., Cui, Y.-F., Wang, Q., Gao, X.-P., Liu, J., Liu, Y.-H., Zhu, S., & Zeng, F.-F. (2021). Physical activity, screen exposure and sleep among students during the pandemic of COVID-19. *Scientific Reports, 11*(1), 8529. https://doi.org/10.1038/s41598-021-88071-4.

Haileamlak, A. (2021). The impact of COVID-19 on health and health systems. *Ethiopian Journal of Health Sciences, 31*(6), 1073–1074. https://doi.org/10.4314/ejhs.v31i6.1.

Haldane, V., De Foo, C., Abdalla, S. M., Jung, A.-S., Tan, M., Wu, S., Chua, A., Verma, M., Shrestha, P., Singh, S., Perez, T., Tan, S. M., Bartos, M., Mabuchi, S., Bonk, M., McNab, C., Werner, G. K., Panjabi, R., Nordström, A., & Legido-Quigley, H. (2021). Health systems resilience in managing the COVID-19 pandemic: Lessons from 28 countries. *Nature Medicine, 27*(6), 964–980. https://doi.org/10.1038/s41591-021-01381-y.

Haldane, V., & Morgan, G. T. (2020). From resilient to transilient health systems: The deep transformation of health systems in response to the COVID-19 pandemic. *Health Policy and Planning*, czaa169. https://doi.org/10.1093/heapol/czaa169.

Health-Related Fitness Measures for Youth: Musculoskeletal Fitness—Fitness Measures and Health Outcomes in Youth—NCBI Bookshelf. (n.d.). Retrieved 16 October 2022, from https://www.ncbi.nlm.nih.gov/books/NBK241310/.

Henriques-Neto, D., Minderico, C., Peralta, M., Marques, A., & Sardinha, L. B. (2020). Test–retest reliability of physical fitness tests among young athletes: The FITescola® battery. *Clinical Physiology and Functional Imaging, 40*(3), 173–182. https://doi.org/10.1111/CPF.12624.

Hestbaek, L., & Cassidy, J. D. (2013). Low back pain across the life course. *Best Practice & Research Clinical Rheumatology, 27*(5), 591–600. https://doi.org/10.1016/J.BERH.2013.09.007.

Hoy, D., Bain, C., Williams, G., March, L., Brooks, P., Blyth, F., Woolf, A., Vos, T., & Buchbinder, R. (2012). A systematic review of the global prevalence of low back pain. *Arthritis and Rheumatism, 64*(6), 2028–2037. https://doi.org/10.1002/ART.34347.

Innocenti, U. O. Life in Lockdown: Child and adolescent mental health and well-being in the time of COVID-19. UNICEF-IRC. Retrieved 8 December 2022, from https://www.unicef-irc.org/publications/1227-life-in-lockdown.html.

Ito, T., Sugiura, H., Ito, Y., Narahara, S., Noritake, K., Takahashi, D., Natsume, K., & Ochi, N. (2022). Physical Functions among Children before and during the COVID-19 Pandemic: A Prospective Longitudinal Observational Study (Stage 1). *International Journal of Environmental Research and Public Health, 19*(18), 11513. https://doi.org/10.3390/ijerph191811513.

James, S. L., Abate, D., Abate, K. H., Abay, S. M., Abbafati, C., Abbasi, N., Abbastabar, H., Abd-Allah, F., Abdela, J., Abdelalim, A., Abdollahpour, I., Abdulkader, R. S., Abebe, Z., Abera, S. F., Abil, O. Z., Abraha, H. N., Abu-Raddad, L. J., Abu-Rmeileh, N. M. E., Accrombessi, M. M. K., … Murray, C. J. L. (2018). Global, regional, and national incidence, prevalence, and years lived with disability for 354 Diseases and Injuries for 195 countries and territories, 1990-2017: A systematic analysis for the Global Burden of Disease Study 2017. *The Lancet, 392*(10159), 1789–1858. https://doi.org/10.1016/S0140-6736(18)32279-7.

Jarnig, G., Kerbl, R., & van Poppel, M. N. M. (2022). The Impact of COVID-19-Related Mitigation Measures on the Health and Fitness Status of Primary School Children in Austria: A Longitudinal Study with Data from 708 Children Measured before and during the Ongoing COVID-19 Pandemic. *Sports, 10*(3), Article 3. https://doi.org/10.3390/sports10030043.

Kamper, S. J., Yamato, T. P., & Williams, C. M. (2016). The prevalence, risk factors, prognosis and treatment for back pain in children and adolescents: An overview of systematic reviews. *Best Practice & Research. Clinical Rheumatology, 30*(6), 1021–1036. https://doi.org/10.1016/j.berh.2017.04.003.

Kędra, A., Plandowska, M., Kędra, P., & Czaprowski, D. (2021). Physical activity and low back pain in children and adolescents: A systematic review. European *Spine Journal : Official Publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 30*(4), 946–956. https://doi.org/10.1007/S00586-020-06575-5.

López-Bueno, R., Calatayud, J., Andersen, L. L., Casaña, J., Ezzatvar, Y., Casajús, J. A., López-Sánchez, G. F., & Smith, L. (2021). Cardiorespiratory fitness in adolescents before and after the COVID-19 confinement: A prospective cohort study. *European Journal of Pediatrics, 180*(7), 2287–2293. https://doi.org/10.1007/s00431-021-04029-8.

Lynch, A. M., Kashikar-Zuck, S., Goldschneider, K. R., & Jones, B. A. (2006). Psychosocial Risks for Disability in Children With Chronic Back Pain. *The Journal of Pain, 7*(4), 244–251. https://doi.org/10.1016/j.jpain.2005.11.001.

Mallah, S. I., Ghorab, O. K., Al-Salmi, S., Abdellatif, O. S., Tharmaratnam, T., Iskandar, M. A., Sefen, J. A. N., Sidhu, P., Atallah, B., El-Lababidi, R., & Al-Qahtani, M. (2021). COVID-19: Breaking down a global health crisis. *Annals of Clinical Microbiology and Antimicrobials, 20*, 35. https://doi.org/10.1186/s12941-021-00438-7.

Manchikanti, L., Singh, V., Datta, S., Cohen, S. P., Hirsch, J. A., & American Society of Interventional Pain Physicians. (n.d.). Comprehensive review of epidemiology, scope, and impact of spinal pain. *Pain Physician, 12*(4), E35-70.

Masiero, S., Carraro, E., Celia, A., Sarto, D., & Ermani, M. (2008). Prevalence of nonspecific low back pain in schoolchildren aged between 13 and 15 years. *Acta Paediatrica, International Journal of Paediatrics, 97*(2), 212–216. https://doi.org/10.1111/j.1651-2227.2007.00603.x.

Mateo-Orcajada, A., González-Gálvez, N., Abenza-Cano, L., & Vaquero-Cristóbal, R. (2022). Differences in Physical Fitness and Body Composition Between Active and Sedentary Adolescents: A Systematic Review and Meta-Analysis. *Journal of Youth and Adolescence, 51*(2), 177–192. https://doi.org/10.1007/s10964-021-01552-7.

Minghelli, B. (2020). Musculoskeletal spine pain in adolescents: Epidemiology of non-specific neck and low back pain and risk factors. *Journal of Orthopaedic Science, 25*(5), 776–780. https://doi.org/10.1016/j.jos.2019.10.008.

Minghelli, B., Oliveira, R., & Nunes, C. (2014). Non-specific low back pain in adolescents from the south of Portugal: Prevalence and associated factors. *Journal of Orthopaedic Science, 19*(6), 883–892. https://doi.org/10.1007/s00776-014-0626-z.

Moore, S. A., Faulkner, G., Rhodes, R. E., Brussoni, M., Chulak-Bozzer, T., Ferguson, L. J., Mitra, R., O'Reilly, N., Spence, J. C., Vanderloo, L. M., & Tremblay, M. S. (2020). Impact of the COVID-19 virus outbreak on movement and play behaviours of Canadian children and youth: A national survey. *The International Journal of Behavioral Nutrition and Physical Activity, 17*, 85. https://doi.org/10.1186/s12966-020-00987-8.

Nawrocka, A., Mynarski, W., Powerska, A., Grabara, M., Groffik, D., & Borek, Z. (2014). Health-oriented physical activity in prevention of musculoskeletal disorders among young Polish musicians. *International Journal of Occupational Medicine and Environmental Health, 27*(1), 28–37. https://doi.org/10.2478/s13382-014-0224-5.

Okuyama, J., Seto, S., Fukuda, Y., Funakoshi, S., Amae, S., Onobe, J., Izumi, S., Ito, K., & Imamura, F. (2021). Mental Health and Physical Activity among Children and Adolescents during the COVID-19 Pandemic. *The Tohoku Journal of Experimental Medicine, 253*(3), 203–215. https://doi.org/10.1620/tjem.253.203.

Ortega, F. B., Ruiz, J. R., Castillo, M. J., & Sjöström, 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.

Parums, D. V. (2021). Editorial: Long COVID, or Post-COVID Syndrome, and the Global Impact on Health Care. Medical Science Monitor : *International Medical Journal of Experimental and Clinical Research, 27*, e933446-1-e933446-2. https://doi.org/10.12659/MSM.933446.

Pfefferbaum, B., & Van Horn, R. L. (2022). Physical Activity and Sedentary Behavior in Children During the COVID-19 Pandemic: Implications for Mental Health. *Current Psychiatry Reports, 24*(10), 493–501. https://doi.org/10.1007/s11920-022-01366-9.

Poussa, M. S., Heliövaara, M. M., Seitsamo, J. T., Könönen, M. H., Hurmerinta, K. A., & Nissinen, M. J. (2005). Development of spinal posture in a cohort of children from the age of 11 to 22 years. *European Spine Journal, 14*(8), 738–742. https://doi.org/10.1007/s00586-004-0701-9.

Resolução do Conselho de Ministros n.o 43-B/2020, de 12 de junho | DRE. (n.d.). Retrieved 28 January 2023, from https://dre.pt/dre/detalhe/resolucao-conselho-ministros/43-b-2020-135711302.

Ricoca Peixoto, V., Vieira, A., Aguiar, P., Carvalho, C., Rhys Thomas, D., & Abrantes, A. (2020). Initial Assessment of the Impact of the Emergency State

Lockdown Measures on the 1st Wave of the COVID-19 Epidemic in Portugal. *Acta Medica Portuguesa, 33*(11), 733–741. https://doi.org/10.20344/amp.14129.

Rossi, M., Pasanen, K., Kokko, S., Alanko, L., Heinonen, O. J., Korpelainen, R., Savonen, K., Selänne, H., Vasankari, T., Kannas, L., Kujala, U., Villberg, J., & Parkkari, J. (2016). Low back and neck and shoulder pain in members and non-members of adolescents' sports clubs: The Finnish Health Promoting Sports Club (FHPSC) study. *BMC Musculoskeletal Disorders, 17*(1), 1–12. https://doi.org/10.1186/s12891-016-1114-8.

Roth-Isigkeit, A., Thyen, U., Stöven, H., Schwarzenberger, J., & Schmucker, P. (2005). Pain among children and adolescents: Restrictions in daily living and triggering factors. *Pediatrics, 115*(2), e152-62. https://doi.org/10.1542/peds.2004-0682.

Rubin, D. I. (2007). Epidemiology and risk factors for spine pain. *Neurologic Clinics, 25*(2), 353–371. https://doi.org/10.1016/j.ncl.2007.01.004.

Schmitz, A.-K., Vierhaus, M., & Lohaus, A. (2013). Pain tolerance in children and adolescents: Sex differences and psychosocial influences on pain threshold and endurance. *European Journal of Pain (London, England), 17*(1), 124–131. https://doi.org/10.1002/j.1532-2149.2012.00169.x.

Shroff, Z. C., Marten, R., Vega, J., Peters, D. H., Patcharanarumol, W., & Ghaffar, A. (2021). Time to reconceptualise health systems. *Lancet (London, England), 397*(10290), 2145. https://doi.org/10.1016/S0140-6736(21)01019-9.

Sunda, M., Gilic, B., Peric, I., Jurcev Savicevic, A., & Sekulic, D. (2021). Evidencing the Influence of the COVID-19 Pandemic and Imposed Lockdown Measures on Fitness Status in Adolescents: A Preliminary Report. *Healthcare, 9*(6), Article 6. https://doi.org/10.3390/healthcare9060681.

Sweeting, H., & West, P. (2002). Gender differences in weight related concerns in early to late adolescence. *Journal of Epidemiology & Community Health, 56*(9), 700–701. https://doi.org/10.1136/jech.56.9.700.

Szita, J., Boja, S., Szilagyi, A., Somhegyi, A., Varga, P. P., & Lazary, A. (2018). Risk factors of non-specific spinal pain in childhood. *European Spine Journal, 27*(5), 1119–1126. https://doi.org/10.1007/s00586-018-5516-1.

Trigueiro, M. J., Massada, L., & Garganta, R. (2013). Back pain in Portuguese schoolchildren: Prevalence and risk factors. *European Journal of Public Health, 23*(3), 499–503. https://doi.org/10.1093/eurpub/cks105.

Tsoukos, A., & Bogdanis, G. C. (2022). The Effects of a Five-Month Lockdown Due to COVID-19 on Physical Fitness Parameters in Adolescent Students: A Comparison between Cohorts. *International Journal of Environmental Research and Public Health, 19*(1), Article 1. https://doi.org/10.3390/ijerph19010326.

Vierola, A., Suominen, A. L., Lindi, V., Viitasalo, A., Ikävalko, T., Lintu, N., Väistö, J., Kellokoski, J., Närhi, M., & Lakka, T. A. (2016). Associations of Sedentary Behavior, Physical Activity, Cardiorespiratory Fitness, and Body Fat Content With Pain Conditions in Children: The Physical Activity and Nutrition in Children Study. *The Journal of Pain, 17*(7), 845–853. https://doi.org/10.1016/J.JPAIN.2016.03.011.

Watson, K., Papageorgiou, A., Jones, G., Taylor, S., Symmons, D., Silman, A., & Macfarlane, G. (2003). Low back pain in schoolchildren: The role of mechanical and psychosocial factors. *Archives of Disease in Childhood, 88*(1), 12–17. https://doi.org/10.1136/adc.88.1.12.

Wu, A., March, L., Zheng, X., Huang, J., Wang, X., Zhao, J., Blyth, F. M., Smith, E., Buchbinder, R., & Hoy, D. (2020). Global low back pain prevalence and years lived with disability from 1990 to 2017: Estimates from the Global Burden of Disease Study 2017. *Annals of Translational Medicine, 8*(6), 299–299. https://doi.org/10.21037/ATM.2020.02.175.

Zheng, W., Suzuki, K., Yokomichi, H., Sato, M., & Yamagata, Z. (2013). Multilevel Longitudinal Analysis of Sex Differences in Height Gain and Growth Rate Changes in Japanese School-Aged Children. *Journal of Epidemiology, 23*(4), 275–279. https://doi.org/10.2188/jea.JE20120164.

CHAPTER VII

CONCLUSION

Our studies confirmed that the prevalence of back pain in children and adolescents is very high, with approximately half of the study population reporting back pain at least once in their lifetime. Our studies also highlight some factors contributing to the increased risk of back pain, namely increasing age, female gender, percentage of body fat, use of electronic devices, especially the use of cell phones and computers. The posture of the thoracic spine, i.e., hyperkyphosis and lateral global tilt of the spine to the left, contribute to an increased risk of back pain. However, there are also some protective factors such as practice of physical activity or sport competitively and video game use.

Posture in the sagittal plane of the different spinal regions proved to be a predictor of static balance, and although it is a weak predictor, it proved to be significant. However, the static balance variables did not prove to be risk predictors of back pain in children and adolescents. Females had higher balance scores and adolescents had higher balance scores than children.

Finally, and taking advantage of the possibility of having conducted the longitudinal study during the first lockdown, we can conclude that the children and adolescents maintained a regular physical activity and even increased the level of physical fitness in almost all parameters. The increase in the push-ups has been shown to be a protective factor in the manifestation of back pain. However, increasing or decreasing regular physical activity has not been shown to have an effect on the manifestation of back pain in children and adolescents.

These data help to deepen the knowledge of the manifestation of back pain in children and adolescents in today’s population.

CHAPTER VIII

CLINICAL AND PRATICAL IMPLICATIONS

The new data presented in this work add to the body of knowledge on topics that remain highly controversial, namely posture and the various risk factors that may be associated with back pain in children and adolescents.

The new habits and lifestyles in today's society, especially among the younger ones, like prolonged television viewing and computer/cell phone use (Baradaran Mahdavi et al., 2021), should be a concern for those responsible for education, but also for society as a whole, in order to promote a healthy lifestyle and thus prevent future health problems, not only in the area of the musculoskeletal system, but also in terms of the general health of our children and young people (Watson et al., 2003).

With the identification of these risk factors related to back pain, described in the studies conducted here, we can run campaigns to raise awareness among the young population and adults about the risks of some behaviors that can be changed to avoid this problem. These campaigns will be conducted in schools, city councils, and with parents and guardians. Indeed, for health professionals who face the problem of back pain daily, this is a more proper way to better manage the clinical condition of the younger population through home recommendations, postural correction interventions, especially in the thoracic region, and the relationship with the other body segments. Postural analysis based on normal reference parameters should be performed by physical therapists to understand the risk of developing back pain in children and adolescents. The reference data used in the studies that make part of this doctoral thesis, namely the study of Furlanetto et al., (2018) can and should be used as a guide for objective assessment by these health professionals.

The relationship between posture and other clinical conditions in children and adolescents deserves new attention, especially the relationship between hyperkyphosis and back pain. It is now known that breathing has a tremendous influence on pain modulation and the autonomic nervous system (Arslan & Ünal Çevik, 2022; Jafari et al., 2017), and the thoracic spine has a natural relationship with breathing. Thus, when hyperkyphosis is present, the mechanical respiratory capacity may be conditioned (Jang et al., 2015; Mummaneni et al., 2006) as well as the ability to respond to pain. This aspect is particularly important in chronic musculoskeletal pain in adults, but also in children and adolescents (Burdge et al., 2022).

Motor control, expressed in balance, is an important aspect related to spine posture (Zurawski et al., 2020), and it is important to stimulate it through exercises that promote the improvement of this motor capacity. The relationship between balance and spine posture in children and adolescents should be an important aspect in the approach of health professionals involved in rehabilitation and prevention, but also of physical educators as promoters of preventive health so that we have healthier adults.

REFERENCES

Arslan, D., & Ünal Çevik, I. (2022). Interactions between the painful disorders and the autonomic nervous system. Agri: Agri (Algoloji) Dernegi'nin Yayin Organidir = *The Journal of the Turkish Society of Algology, 34*(3), 155–165. https://doi.org/10.14744/agri.2021.43078.

Baradaran Mahdavi, S., Riahi, R., Vahdatpour, B., & Kelishadi, R. (2021). Association between sedentary behavior and low back pain; A systematic review and meta-analysis. *Health Promotion Perspectives, 11*(4), 393–410. https://doi.org/10.34172/hpp.2021.50.

Burdge, J., Jhumka, Z. A., Bravo, I. M., & Abdus-Saboor, I. (2022). Taking a deep breath: How a brainstem pathway integrates pain and breathing. *Neuron, 110*(5), 739–741. https://doi.org/10.1016/j.neuron.2022.02.003.

Furlanetto, T. S., Sedrez, J. A., Candotti, C. T., & Loss, J. F. (2018). Reference values for Cobb angles when evaluating the spine in the sagittal plane: A systematic review with meta-analysis. *Motricidade, 14*(2–3), Article 2–3. https://doi.org/10.6063/motricidade.10890.

Jafari, H., Courtois, I., Van den Bergh, O., Vlaeyen, J. W. S., & Van Diest, I. (2017). Pain and respiration: A systematic review. *Pain, 158*(6), 995–1006. https://doi.org/10.1097/j.pain.0000000000000865.

Jang, H.-J., Kim, M.-J., & Kim, S.-Y. (2015). Effect of thorax correction exercises on flexed posture and chest function in older women with age-related hyperkyphosis. *Journal of Physical Therapy Science, 27*(4), 1161–1164. https://doi.org/10.1589/jpts.27.1161.

Mummaneni, P. V., Deutsch, H., & Mummaneni, V. P. (2006). Cervicothoracic kyphosis. *Neurosurgery Clinics of North America, 17*(3), 277–287, vi. https://doi.org/10.1016/j.nec.2006.05.007.

Watson, K., Papageorgiou, A., Jones, G., Taylor, S., Symmons, D., Silman, A., & Macfarlane, G. (2003). Low back pain in schoolchildren: The role of mechanical and psychosocial factors. *Archives of Disease in Childhood, 88*(1), 12–17. https://doi.org/10.1136/adc.88.1.12.

Zurawski, A. L., Kiebzak, W. P., Kowalski, I. M., Sliwinski, G., & Sliwinski, Z. (2020). Evaluation of the association between postural control and sagittal curvature of the spine. *PLoS ONE, 15*(10). https://doi.org/10.1371/JOURNAL.PONE.0241228.

CHAPTER IX

SUGGESTION FOR FURTHER STUDIES

There is still much to study about the factors that influence back pain. Because the phenomenon of pain is extremely complex, it should be addressed as comprehensively as possible, with more robust methods and more sophisticated means of analysis.

That's why we think it's important:

i. To develop longer longitudinal studies, that is, with a longer follow-up of individuals, which has already been done in other countries, but not in Portugal.

ii. Extend this study to other parts of the country to obtain more comprehensive characterizing data.

iii. Study the younger population in different contexts, i.e., rural and urban areas, and to identify the risk factors for back pain in children and adolescents in these two settings.

iv. To delve deeper into the relationship between sleep quality and postural changes in children and adolescents,

v. Investigate the relationship between mental health and posture and vice versa through combined studies between physiotherapy and psychology, taking this study as a starting point and linking it to psychological measurement instruments.

APPENDIXES AND ANNEXES

APPENDIX A – Is flexibility associated with body composition? Bioimpedance analysis in children and adolescents. 9th Portuguese Congress on Biomechanics (2021).

Is flexibility associated with body composition? Bioimpedance analysis in children and adolescents.

Nelson Azevedo[1], José Carlos Ribeiro[2], Leandro Machado[3].
[1]CICS, ISAVE, Faculdade de Desporto da Universidade do Porto, Portugal, up200505971@fade.up.pt
[2] CIAFEL, Faculdade de Desporto da Universidade do Porto, Portugal, jribeiro@fade.up.pt
[3]CIFI2D, LABIOMEP, Faculdade de Desporto da Universidade do Porto, Portugal, lmachado@fade.up.pt

ABSTRACT
Flexibility is an important parameter of musculoskeletal assessment. It is related to sports performance, but also to health conditions. Flexibility is part of the characterization of the global physical fitness of children and adolescents, as is the assessment of body composition. The literature did not report strong evidence between the levels of flexibility and the variables related to body composition.
To understand the existence of an association between body composition and flexibility, a cross-sectional study in children and adolescents was carried out using valid instruments to assess flexibility and body composition. The results suggest an association between bioimpedance values and flexibility, while observing differences between genders and ages.

Keywords: Flexibility, children, adolescents, physical fitness, body composition.

INTRODUCTION
Physical fitness analysis in children and adolescents is extremely important because it may serve as a predictor of future health in children, both in terms of cardiovascular diseases as well as musculoskeletal diseases, especially diseases of the spine (Ruiz et al., 2009). In Portugal, the benchmark for assessing physical fitness in the education system is through the FITescola® program. This program is divided into 3 specific areas, namely aerobic fitness, body composition and neuromuscular fitness. Flexibility is assessed in the neuromuscular fitness area. Flexibility is an important parameter for sports evaluation (Arnason et al., 2004), but also for musculoskeletal health (Martim & Simas, 2012). The benefits of a good physical fitness level are not only limited to the physical component but also to the quality of life in children (Garber et al., 2011). There are several factors that contribute to the different levels of flexibility, including the parameters of body composition (Eler, 2018). Studies have found differences between genders and levels of flexibility (Eler, 2018; Haugen, Høigaard, & Seiler, 2014), but there is little evidence of the association that body composition parameters have with flexibility in children and adolescents (Ganley et al., 2011).

MATERIALS AND METHODS
A cross-sectional study was carried out with children from some schools in the north of Portugal, in Braga district, between October and December 2019. As instruments, a sample characterization questionnaire, a body composition analyser (InBody 230) and the FITescola® test battery was used. The test battery is divided into three areas, aerobic condition, neuromuscular fitness, and body composition. Flexibility was included in the neuromuscular fitness and was assessed by the seat and reach test (assessing the flexibility of the lower limbs). Three categories were created according to the performance of each student (low flexibility, healthy / normal flexibility, and athletic / high flexibility). The categorization was done by age and according to the FITescola® guidelines. The application of the instruments took place at the same moment of evaluation, during a physical education class. Of a total of 1907 children whose caretakers freely signed the informed consent, 1491 (78.2%) agreed to participate in the study, that included boys and girls aged 9 to 19 years.

Statistical analysis
Descriptive statistics was used to characterize the study sample. Normality of the data was tested, and Mann–Whitney U-test was used to estimate differences in the studied variables between the two groups (gender), and multinomial logistic regression was used to calculate the odds ratio for body composition and flexibility. The statistical significance was set as $\alpha=0.05$. IBM SPSS Statistic version 26 was used.

RESULTS AND DISCUSSION
In the analysis, significant differences were observed regarding all variables between genders, except for age ($p=0.261$).
To calculate the Odds Ratio (OR), a multinomial logistic regression was performed considering flexibility as the dependent variable (3 categories: low flexibility profile - LFP, normal flexibility profile – NFP, and athletic flexibility profile - AFP) and the remaining variables as independent variables. The reference category is the normal flexibility profile.

Table 1. Logistic regression with flexibility and body composition. Considering normal flexibility as reference.

	Low flexibility profile					Athletic flexibility profile				
	B	Odds Ratio	95% CI		Sig.	B	Odds Ratio	95% CI		Sig.
			Lower Bound	Upper Bound				Lower Bound	Upper Bound	
Intercept	3.751				0.000	-3.633				0.000
Body Fat Mass	0.027	1.028	0.729	1.449	0.876	0.053	1.054	0.657	1.692	0.827
Fat Free Mass	-0.108	0.898	0.643	1.254	0.527	0.428	1.534	0.975	2.414	0.064
Skel. Musc. Mass	-0.495	**0.610**	0.449	0.828	**0.002**	-0.164	0.848	0.564	1.277	0.431
Body Mass Index	-0.332	0.718	0.496	1.039	0.079	-0.067	0.935	0.557	1.569	0.799
Percent Body Fat	0.033	1.033	0.749	1.426	0.842	0.033	1.034	0.667	1.603	0.882
Basal Met. Rate	-0.408	**0.665**	0.445	0.995	**0.047**	0.348	1.416	0.826	2.427	0.205
Waist-Hip Ratio	0.365	**1.440**	1.176	1.764	**0.000**	0.389	**1.475**	1.111	1.960	**0.007**
Age	-0.200	**0.819**	0.774	0.867	**0.000**	0.120	**1.127**	1.038	1.223	**0.004**

By analysing the data, in table 1, we can observe that, an increase in skeletal muscle mass (SMM) reduced the probability by 39% (OR: 0.610; CI: 0.449-0.828) of belonging to the LFP, comparatively to be in the NFP.
The same is observed with the increase of basal metabolic rate (BMR), were we can notice that an increase in this variable reduces the probability to be in the LFP, comparatively to be in the reference category.
The waist-hip ratio (WHR) showed a positive relationship in both groups, where increases in WHR increase the probability of belonging to the LFP and AFP when compared to the NFP.
The probability of belonging to the LFP is lower with increasing age (18%; OR: 0.819; CI: 0.774-1.867), however, at older ages the probability of belonging to the AFP increases by about 13% when compared to the reference category (OR: 1.127; CI: 1,038-1.223).
After analysing the variables together, we carry out the evaluation separately by gender.
In the female gender, the increase in body fat mass (BFM) is associated with an increased probability of belonging to the LFP group (88%; OR: 1.883; CI: 1.055-3,361). On the other hand, the higher levels of the body mass index (BMI) increase the probability of belonging to the LFP group by 53% (OR: 0.457; CI: 0.256-0.853).
In females, age increases the probability of belonging to the AFP group by 27% (OR: 1.269; CI: 1.134-1.420).
In males, with the increase in SMM and age variables, the probability of belonging to the LFP group reduced by 47% and 29% respectively (OR: 0.533; CI: 0.335-0.848 and OR: 0.709; CI: 0.646-0.778). when we analyse the probability of belonging to the group of greater flexibility in males, an increase in fat free mass (FFM) increases the probability of belonging to the AFP group when compared to the NFP (OR: 2,701; CI: 1.190-6.128).
These data indicate that there are differences in the genres regarding flexibility, and that this is mediated by several factors, including parameters obtained through bio-impedance. In the specific work of flexibility, both in school and in sports in children and adolescents, the use of bio-impedance seems to be an important assessment tool.

REFERENCES:

[1] Arnason, A., Sigurdsson, S. B., Gudmundsson, A., Holme, I., Engebretsen, L., & Bahr, R. (2004). Physical Fitness, Injuries, and Team Performance in Soccer. *Med. Sci. Sports Exerc*, *36*(2), 278–285.

[2] Eler, N. (2018). The Relationship between Body Composition and Physical Fitness Parameters in Children. *International Education Studies*, *11*(9), 71.

[3] Ganley, K. J., Paterno, M. V., Miles, C., Stout, J., Brawner, L., Girolami, G., & Warren, M. (2011). Health-Related Fitness in Children and Adolescents. *Pediatric Physical Therapy*, *23*(3), 208–220.

[4] Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., … Swain, D. P. (2011). Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Medicine and Science in Sports and Exercise*, *43*(7), 1334–1359.

[5] Haugen, T., Høigaard, R., & Seiler, S. (2014). Normative data of BMI and physical fitness in a Norwegian sample of early adolescents. *Scandinavian Journal of Public Health*, *42*(1), 67–73.

[6] Martim, J., & Simas, M. (2012). *Flexibilidade e Lesões no Voleibol. 1. 48-53.*

[7] Ruiz, J. R., Castro-Piñero, J., Artero, E. G., Ortega, F. B., Sjöström, M., Suni, J., & Castillo, M. J. (2009, November 1). Predictive validity of health-related fitness in youth: A systematic review. *British Journal of Sports Medicine*, Vol. 43, pp. 909–923.

APPENDIX B – Trunk body composition and relationship with spinal flexion mobility.
10th Portuguese Congress on Biomechanics (2023).

TRUNK BODY COMPOSITION AND RELATIONSHIP WITH SPINAL FLEXION MOBILITY

***Nelson Azevedo* [1], *José Carlos Ribeiro* [2] *and Leandro Machado* [3]**

[1] *CICS, ISAVE, Faculdade de Desporto da Universidade do Porto, 4200-450 Porto, Portugal;*
nelson.azevedo@docente.isave.pt

[2] *CIAFEL, ITR, Faculdade de Desporto da Universidade do Porto, 4200-450 Porto, Portugal;*
jribeiro@fade.up.pt

[3] *CIFI2D, LABIOMEP, Faculdade de Desporto da Universidade do Porto, 4200-450 Porto, Portugal;*
lmachado@fade.up.pt

KEYWORDS: Spine mobility; body composition; children; adolescents.

ABSTRACT: *Spinal mobility depends on many factors that are reflected in the health and functionality of the spine itself. These factors are increasingly being studied in the adult population, but there are still few conclusive data in the younger population. Therefore, a cross-sectional study was conducted to examine the relationship between trunk body composition and spinal flexion mobility in children and adolescents. The results indicate that body composition presents a significantly association with maximum flexion range of motion of the spine movement. This association is positive in the pelvic region and negative in the lumbar and thoracic spine.*

1 INTRODUCTION

The spinal health of children and adolescents is of increasing importance in today's society[1], not just by the impact on the future adult population, but also because of the opportunity to intervene in primary prevention. Mobility is an important factor in the health of the spine itself and is dependent on several factors[2]. Body composition is an assessment that helps us understand the metabolic state of the individual[3]. Therefore, we ask the question: are trunk body composition values related to spinal mobility in children and adolescents?

2 MATERIALS AND METHODS

A cross-sectional study was conducted with a population of children and adolescents between 9 and 19 years of age to evaluate spinal flexion mobility in relation to body composition of the trunk.

The sample consisted of 1463 elements, 719 female and 744 male. The mean age was 13.93 years (SD: 2.4). As instruments, a body composition analyser InBody 230® was used to assess body composition of the trunk and the Spinal Mouse® was used to assess maximum flexion range of motion of the spine. The trunk body composition parameters evaluated were trunk fat free mass (FFM), and trunk fat mass (BFM).The movements evaluated were pelvic, lumbar and thoracic flexion.

STATISTICAL ANALYSIS

Descriptive statistics were performed to characterize the sample. Multiple linear regression was used to test whether trunk body composition parameters significantly predicted spinal and pelvic flexion mobility in children and adolescents.

3 RESULTS

The results of the evaluations indicate that body composition presents a significantly association with maximum flexion range of motion of the spine.

For pelvic flexion, this association is positive for both FMF and BFM, and the contribution of FFM is clearly higher than that of BFM (Tab. 1). For the lumbar spine, this association is negative, i.e., the higher the FFM and BFM, the lower the maximum flexion of the lumbar spine (Tab. 2). The association is slightly higher in FFM compared to BFM in the lumbar spine.

In the thoracic spine, there is still a negative relationship between the FFM and BFM variables and the maximum range of motion for thoracic spine flexion, but in this case the contribution of the BFM is greater than that of the FFM (Tab. 3).

Tab. 1. Pelvic flexion.

(R2 = 0.04, F (3, 1460) = 32.53, p = <0.001)				
	B	β	t	***p*-Value**
Const.*	22.208		17.124	<0.001
FFM	0.483	0.184	6.921	**<0.001**
BFM	0.155	0.055	2.082	**0.038**

*Constant

Tab. 2. Lumbar flexion.

(R2 = 0.09, F (3, 1460) = 74.77, p = <0.001)				
	B	β	t	***p*-Value**
Const.*	76.871		77.373	<0.001
FFM	-0.451	-0.219	-8.438	**<0.001**
BFM	-0.353	-0.161	-6.193	**<0.001**

*Constant

Tab. 3. Thoracic flexion.

(R2 = 0.05, F (3, 1460) = 38.78, p = <0.001)				
	B	β	t	***p*-Value**
Const.*	23.032		18.013	<0.001
FFM	-0.155	-0.060	-2.253	**0.024**
BFM	-0.555	-0.201	-7.568	**<0.001**

*Constant

3 DISCUSSION

The data from our study highlights the relationship between mobility during maximum flexion range of motion of the spine and trunk body composition.

The associations between variables show different results depending on the region of the spine: In the pelvis, this association is positive, but in the lumbar and thoracic spine, this association is negative. The FFM shows a greater association in the pelvis and lumbar spine, but in opposite directions, while this association is much lower in the thoracic spine. The BFM also shows a relationship with mobility, mainly in the lumbar and thoracic spine and to a much lesser extent in the pelvis.

Recent studies in adults have demonstrated the relationship between body composition and biomechanical changes associated with degenerative processes of the lumbar spine[4]. In children, spinal mobility and body composition has been shown to influence low back pain[5], but a relationship between these two indicators has not been established. These results may contribute to a better understanding of spinal mobility in children and adolescents with different body compositions and to deepen the knowledge between these two assessment parameters.

REFERENCES

[1] T. JB, G. AP, G. SZ, and C. CE, 'Incidence and risk factors for first-time incident low back pain: a systematic review and meta-analysis', The spine journal : official journal of the North American Spine Society, vol. 14, no. 10, pp. 2299–2319, Oct. 2014.

[2] I. A. Saidu, S. M. Maduagwu, A. D. Abbas, O. O. Adetunji, and A. M. Jajere, 'Lumbar spinal mobility changes among adults with advancing age', J Midlife Health, vol. 2, no. 2, pp. 65–71, Jul. 2011.

[3] M. TAKESIAN et al., 'TRUNK BODY MASS INDEX: A NEW REFERENCE FOR THE ASSESSMENT OF BODY MASS DISTRIBUTION', Arq Bras Cir Dig, vol. 31, no. 1, p. e1362, Jun. 2018.

[4] S. Baek, H. Park, and G. Kim, 'Associations Between Trunk Muscle/Fat Composition, Narrowing Lumbar Disc Space, and Low Back Pain in Middle-Aged Farmers: A Cross-Sectional Study', Ann Rehabil Med, vol. 46, no. 3, pp. 122–132, Jun. 2022.

[5] A. Cejudo, A. Ginés-Díaz, O. Rodríguez-Ferrán, F. Santonja-Medina, and P. Sainz de Baranda, 'Trunk Lateral Flexor Endurance and Body Fat: Predictive Risk Factors for Low Back Pain in Child Equestrian Athletes', Children, vol. 7, no. 10, Art. no. 10, Oc

ANNEX A: The FITescola® program reference values.

TABELA DE VALORES DE REFERÊNCIA (RAPAZES)

PROGRAMA: FIT ESCOLA

PROMOTORES: REPÚBLICA PORTUGUESA – Educação; Direção-Geral da Educação; FMH

APTIDÃO AERÓBIA

Idade	Vaivém – Zona Saudável ≥ – VO_2 (ml/kg/min)	Vaivém – Zona Saudável ≥ – N.º de Percursos	Vaivém – Perfil Atlético ≥ – VO_2 (ml/kg/min)	Vaivém – Perfil Atlético ≥ – N.º de Percursos	Milha – Zona Saudável – VO_2 ≥ (ml/kg/min)	Milha – Zona Saudável – Tempo ≤ (min)	Milha – Perfil Atlético – VO_2 ≥ (ml/kg/min)	Milha – Perfil Atlético – Tempo ≤ (min)
9	40,2	13	52,1	47	40,2	9,39	52,1	6,06
10	40,2	16	52,1	50	40,2	9,46	52,1	6,09
11	40,2	20	52,4	54	40,2	9,53	52,4	6,08
12	40,3	23	53,0	59	40,3	9,57	53,0	6,04
13	41,1	28	54,7	67	41,1	9,40	54,7	5,48
14	42,5	36	57,1	77	42,5	9,09	57,1	5,27
15	43,6	42	58,8	85	43,6	8,47	58,8	5,14
16	44,1	47	59,8	91	44,1	8,41	59,8	5,08
17	44,2	50	59,7	94	44,2	8,44	59,7	5,10
18+	44,3	53	59,3	96	44,3	8,47	59,3	5,15

COMPOSIÇÃO CORPORAL

Idade	IMC (kg/m²) – Zona Saudável >	IMC (kg/m²) – Zona Saudável <	Perímetro da Cintura (cm) – Zona Saudável <	Massa Gorda (%) – Zona Saudável <
9	13,6	18,2	77,1	20,7
10	13,9	18,8	80,1	22,5
11	14,2	19,5	82,6	23,7
12	14,7	20,4	85,1	23,7
13	15,2	21,3	87,0	22,9
14	15,7	22,2	88,9	21,4
15	16,3	23,1	90,5	20,2
16	16,7	23,9	91,8	20,2
17	17,1	24,6	92,7	21,0
18+	18,5	25,0	93,4	22,3

APTIDÃO NEUROMUSCULAR

Idade	Abdominais (Nº repetições) – Zona Saudável ≥	Abdominais – Perfil Atlético ≥	Flexões (Nº repetições) – Zona Saudável ≥	Flexões – Perfil Atlético ≥	Impulsão Horizontal (cm) – Zona Saudável ≥	Impulsão Horizontal – Perfil Atlético ≥	Impulsão Vertical (cm) – Zona Saudável ≥	Impulsão Vertical – Perfil Atlético ≥	Agilidade 4X10 m (s) – Zona Saudável ≤	Agilidade 4X10 m – Perfil Atlético ≤	Velocidade 40 m (s) – Zona Saudável ≤	Velocidade 40 m – Perfil Atlético ≤	Velocidade 20 m (s) – Zona Saudável ≤	Velocidade 20 m – Perfil Atlético ≤	Senta e Alcança (cm) – Zona Saudável ≥	Senta e Alcança – Perfil Atlético ≥	Flexibilidade dos Ombros (S/N) – Zona Saudável
9	9	47	6	17	102,1	160,0	15,7	24,7	13,10	11,98	8,27	7,19	4,42	3,91	20,3	29,3	Sim (S) = Contato das pontas dos dedos atrás das costas em ambos os braços
10	12	47	7	21	110,2	170,2	17,2	27,9	12,80	11,65	7,94	6,92	4,28	3,78	20,3	29,3	
11	15	54	8	21	119,0	180,4	18,8	31,0	12,50	11,38	7,63	6,66	4,14	3,66	20,3	28,9	
12	18	60	10	21	128,4	190,6	20,6	34,2	12,20	11,11	7,33	6,41	4,01	3,55	20,3	28,8	
13	21	66	12	22	135,4	197,3	21,7	36,4	12,00	10,90	7,04	6,18	3,89	3,45	20,3	29,2	
14	24	71	14	24	151,5	213,3	25,1	41,0	11,70	10,60	6,76	5,97	3,78	3,36	20,3	30,4	
15	24	71	16	27	165,4	224,4	28,2	44,7	11,20	10,20	6,49	5,77	3,68	3,29	20,3	31,9	
16	24	71	18	29	175,9	231,8	30,0	47,2	10,90	9,90	6,24	5,59	3,58	3,22	20,3	33,5	
17	24	71	18	32	184,2	239,0	31,1	49,1	10,90	9,90	6,00	5,42	3,50	3,17	20,3	34,5	
18+	24	71	18	34	203,2	251,7	35,3	53,2	10,40	9,49	5,77	5,27	3,42	3,13	20,3	35,0	

TABELA DE VALORES DE REFERÊNCIA (RAPARIGAS)

PROGRAMA: FIT ESCOLA

PROMOTORES: REPÚBLICA PORTUGUESA – Educação; Direção-Geral da Educação; FMH

APTIDÃO AERÓBIA

Idade	Vaivém – Zona Saudável ≥ – VO_2 (ml/kg/min)	Vaivém – Zona Saudável ≥ – N.º de Percursos	Vaivém – Perfil Atlético ≥ – VO_2 (ml/kg/min)	Vaivém – Perfil Atlético ≥ – N.º de Percursos	Milha – Zona Saudável – VO_2 ≥ (ml/kg/min)	Milha – Zona Saudável – Tempo ≤ (min)	Milha – Perfil Atlético – VO_2 ≥ (ml/kg/min)	Milha – Perfil Atlético – Tempo ≤ (min)
9	40,2	13	46,8	32	40,2	8,46	46,8	6,47
10	40,2	16	46,8	35	40,2	8,46	46,8	6,47
11	40,2	20	47,1	39	40,2	8,46	47,1	6,43
12	40,1	22	47,3	43	40,1	8,48	47,3	6,39
13	39,7	25	46,9	45	39,7	8,58	46,9	6,45
14	39,4	27	46,5	47	39,4	9,05	46,5	6,51
15	39,1	29	45,7	48	39,1	9,13	45,7	7,02
16	38,9	32	45,3	50	38,9	9,18	45,3	7,08
17	38,8	35	44,6	51	38,8	9,21	44,6	7,20
18+	38,6	37	43,1	50	38,6	9,26	43,1	7,46

COMPOSIÇÃO CORPORAL

Idade	IMC (kg/m²) – Zona Saudável >	IMC (kg/m²) – Zona Saudável <	Perímetro da Cintura (cm) – Zona Saudável <	Massa Gorda (%) – Zona Saudável <
9	13,3	18,7	66,8	22,7
10	13,7	19,4	68,9	24,4
11	14,1	20,3	70,8	25,8
12	14,7	21,3	72,5	26,8
13	15,2	22,3	74,2	27,8
14	15,7	23,1	75,7	28,6
15	16,0	23,8	76,8	29,2
16	16,3	24,3	77,7	29,8
17	16,4	24,6	78,5	30,5
18+	18,5	25,0	79,2	31,4

APTIDÃO NEUROMUSCULAR

Idade	Abdominais (Nº repetições) – Zona Saudável ≥	Abdominais – Perfil Atlético ≥	Flexões (Nº repetições) – Zona Saudável ≥	Flexões – Perfil Atlético ≥	Impulsão Horizontal (cm) – Zona Saudável ≥	Impulsão Horizontal – Perfil Atlético ≥	Impulsão Vertical (cm) – Zona Saudável ≥	Impulsão Vertical – Perfil Atlético ≥	Agilidade 4X10 m (s) – Zona Saudável ≤	Agilidade 4X10 m – Perfil Atlético ≤	Velocidade 40 m (s) – Zona Saudável ≤	Velocidade 40 m – Perfil Atlético ≤	Velocidade 20 m (s) – Zona Saudável ≤	Velocidade 20 m – Perfil Atlético ≤	Senta e Alcança (cm) – Zona Saudável ≥	Senta e Alcança – Perfil Atlético ≥	Flexibilidade dos Ombros (S/N) – Zona Saudável
9	9	39	6	14	108,4	170,9	17,9	29,9	13,20	11,73	8,55	7,51	4,55	4,02	22,9	31,2	Sim (S) = Contato das pontas dos dedos atrás das costas em ambos os braços
10	12	39	7	15	110,8	172,4	18,3	30,4	13,10	11,67	8,23	7,23	4,43	3,90	22,9	31,2	
11	15	46	7	15	113,3	173,8	18,6	30,8	13,00	11,61	7,97	7,00	4,32	3,80	25,4	31,4	
12	18	53	7	15	115,8	175,3	19,0	31,3	12,90	11,55	7,77	6,82	4,24	3,73	25,4	32,1	
13	18	57	7	16	118,1	176,4	19,0	31,3	12,80	11,50	7,62	6,69	4,19	3,68	25,4	33,3	
14	18	59	7	16	121,8	179,6	20,0	32,5	12,70	11,40	7,52	6,61	4,16	3,66	25,4	34,6	
15	18	62	7	17	123,0	179,0	20,3	32,8	12,70	11,40	7,49	6,58	4,16	3,66	30,5	35,3	
16	18	63	7	18	126,0	180,4	20,9	33,6	12,60	11,30	7,51	6,60	4,18	3,69	30,5	35,6	
17	18	65	7	19	129,5	183,4	20,5	33,0	12,60	11,40	7,58	6,67	4,23	3,75	30,5	36,0	
18+	18	66	7	19	131,9	184,2	20,5	34,0	12,60	11,40	7,72	6,79	4,31	3,83	30,5	36,3	

ANNEX B: Informed Consent.

U. PORTO
FACULDADE DE DESPORTO
UNIVERSIDADE DO PORTO

Declaração de Autorização para participação num estudo de Avaliação da postura do Aluno

Este documento tem o propósito de convidar o aluno (seu educando) a participar num estudo de avaliação postural com recurso a instrumentos avançados de análise postural e a sua relação com os níveis de atividade física, que irá decorrer no Agrupamento de Escolas Padre Benjamim Salgado. Este estudo está inserido no meu projeto de doutoramento em Fisioterapia, na Universidade do Porto.

O aumento na incidência de dores nas costas em crianças e adolescentes e a relação existente entre as queixas apresentadas na infância e na vida adulta estão na base de vários programas de rastreio escolar. Desta forma surgiu a necessidade de desenvolver um estudo para rastreio precoce das alterações posturais nas nossas crianças e jovens. Os instrumentos de avaliação a utilizar serão: Spinal Mouse (instrumento não invasivo de avaliação e medição da coluna), plataforma de pressões plantares, a avaliação da composição corporal será feita através do Inbody 230 (medição da bioimpedância) e será utilizado um questionário online para aferir os hábitos posturais e hábitos de atividade física, assim como dados gerais da história clínica do aluno. Os métodos utilizados não são invasivos, não utilizam radiação e não são dolorosos. Desta forma não existem riscos para a saúde do seu educando. As avaliações durarão cerca de 15 minutos e serão feitas no início e no final do ano letivo nas aulas de Educação Física.

A participação é voluntária e pode recusar a participação do seu educando. Caso decida participar neste estudo é importante ter conhecimento que pode desistir a qualquer momento, sem qualquer tipo de consequências para si ou para o seu educando. Estou disponível para esclarecer dúvidas que surjam.

Os dados apenas serão apresentados de forma codificada, pelo que não serão divulgados dados sensíveis com a identificação pessoal.

Após a recolha e tratamento dos dados, caso se verifiquem anomalias posturais significativas, os encarregados de educação serão informados sobre as possíveis alterações detetadas no estudo, com o aconselhamento sobre o serviço de saúde a recorrer para uma avaliação clínica mais detalhada.

Pessoa responsável pelo estudo:

- Nelson João Cunha Azevedo
- Email: nelson.azevedo@isave.pt
- Telefone: 936551655

✂ ....

(recortar pelo tracejado)

Eu abaixo assinado(a)____, portador(a) do BI/CC nº___________________, emitido pelo Arquivo de Identificação de________________, em_____ de_______________de__, declaro que autorizo o meu educando____, do _______ Ano, da Turma______, nº ______; nascido a _____/____/______, e portador do BI/CC nº _____________________a participar neste estudo de avaliação postural.

Assinatura do encarregado(a) de educação: ___________________________________

ANNEX C: Ethics Committee of FADEUP - University of Porto (CEFADE 50, 2019).

Declaração

Para os devidos efeitos, declara-se que o projeto CEFADE 50 2019, intitulado "Dor de coluna vertebral em crianças e adolescentes: avaliação das alterações posturais; fatores de risco associados e abordagens preventivas.", submetido à Comissão de Ética da Faculdade de Desporto da Universidade do Porto, por Nelson João Cunha Azevedo, foi aprovado, por ter em conta os requisitos éticos recomendados.

Porto e Faculdade de Desporto, 14 de Janeiro de 2020

A Presidente da Comissão de Ética

Zélia Maria Matos de Almeida Roque Pinto

Rua Dr. Plácido Costa, 91
4200 Porto, Portugal
Telefone 351220425200
Telefax 351225500689