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ORIGINAL PAPER

Postural, behavioural and cognitive effects of sit-stand desk use in primary school children – a crossover intervention pilot study

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ABSTRACT

Introduction and aim. This study explores the effects of implementing stand-biased desks in a classroom setting on physical posture, cognitive performance, and attention in elementary school students aged 11 to 12 years old.

Material and methods. The study group consisted of 51 boys from 5th and 6th grades. A crossover intervention design was employed, where students alternated between using traditional and sit-stand desks over the course of the study lasting three months. Anthropometric measurements, posture assessments, and cognitive tests (the d2 Test of Attention and Stroop), were conducted at three intervals (T1/T2/T3): initial, mid-intervention, and post-intervention.

Results. During the intervention, significant changes were observed in anthropometric parameters, except for a decrease in body fat percentage. Cognitive testing revealed significant improvements in attentiveness and cognitive control when using the sit-stand desks. Specifically, the d2 test indicated enhanced concentration performance and test effectiveness, particularly when conducted in a standing position. The Stroop test also showed improvements in both time and corrected errors between the second and third assessments.

Conclusion. The findings suggest that sit-stand desks may associate with better weight distribution and improved posture, with positive effects on attentiveness and cognitive performance of schoolchildren.

Keywords. attention, cognitive function, elementary school pupils, posture, sedentary behavior, sit-stand desks

Introduction

In the context of primary education, the increasing prevalence of sedentary behavior among schoolchildren has raised significant concerns about its negative impact on physical health, cognitive development, associated with various health risks, including obesity, cardiovascular diseases, and metabolic disorders, and impaired cognitive function,[1–3] academic achievement, and overall well-being. Traditional classroom settings, characterized by extended periods of sitting, have been identified as a contributing factor to sedentary behaviors. The use of sit-stand desks in educational settings has gained increasing attention as an intervention to reduce sedentary behavior among schoolchildren and enhance various aspects of their physical and cognitive development. Numerous studies have suggested that the use of sit-stand desks, as an alternative to traditional seated desks, is seen as a feasible and effective method to integrate movement into the classroom, fostering both physical health and cognitive engagement:[4,5] by allowing children to alternate between sitting and standing positions, these desks are designed to increase energy

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expenditure and reduce sedentary time, enhance classroom engagement, improve executive functions (attention, working memory) and behavioral outcomes without disrupting academic activities.

However, while the theoretical benefits are compelling, empirical evidence remains mixed, highlighting the need for further investigation to clarify the specific conditions under which standing desks might prove effective.[6,7] The current research landscape reveals significant gaps in understanding the long-term cognitive effects of standing desks on schoolchildren. Many studies are short-term, lack randomized controlled designs, or are limited by small sample sizes, thereby reducing the generalizability of their findings.

This paper builds on previous research by providing a comprehensive review of the literature on standing desks and identifying some of the key gaps by conducting a crossover intervention study to evaluate the cognitive benefits of standing desks in a primary school setting. The study will focus on their impact on physical activity levels and cognitive outcomes in children, providing a comprehensive understanding of how standing desks can influence their attention. By employing a robust experimental design, this research seeks to contribute valuable insights into the efficacy of standing desks as a tool for enhancing educational and health benefits in schools and produce implications for educational policy and practice, providing a nuanced understanding of how environmental modifications in classrooms can support holistic primary schoolchildren development. The theoretical foundation of the sit-stand desk intervention is based on the idea that physical activity can improve the overall well-being of schoolchildren, as well as some of significant health-related parameters and cognitive functions.

Based on the analysis presented above, it is possible to conclude that despite the growing body of reporting promising benefits of sit-stand desks, several gaps remain in the literature. First, while the physical activity benefits of sit-stand desks are well-documented, their direct impact on cognitive functions such as attention and executive function needs further exploration. Second, most studies focus on short-term interventions, and long-term effects on physical activity, cognitive function, and academic performance are less explored.[4] Many studies suffer from methodological weaknesses,[6] such as small sample sizes, which require further investigation to prove the reliability and generalizability of findings. Additionally, the practicality of implementing sit-stand desks in classrooms poses challenges. In a similar fashion, Sherry et al. reported logistical issues such as classroom space constraints and the need for ergonomic training for both pupils and teachers.[8–10] There is also a need for more detailed qualitative research to understand the experiences and perspectives of pupils, teachers, and parents regarding the use of sit-stand desks.[11] Furthermore, the heterogeneity in study designs, outcomes measured, and intervention implementations makes it difficult to draw firm conclusions. For instance, variations in desk types (e.g., fixed height vs. adjustable height), the duration of standing, and the specific cognitive and academic measures used complicate comparisons across studies.[12] Recent advances in computer vision-based activity recognition, extended reality–enabled learning environments, and reliable human-movement signal acquisition further support the view that classroom ergonomics and technology-mediated designs can meaningfully influence posture, engagement, and cognitive outcomes. These works provide additional methodological and contextual grounding for our sit-stand desk intervention study.[13,14] Research is needed to explore the differential impact of sit-stand desks on various pupil/student populations, including those with attention-related disorders such as ADHD. Future studies should also investigate the optimal duration and frequency of standing periods to maximize cognitive benefits without causing fatigue or discomfort. These challenges highlight the necessity for collecting more data to gain solutions to address potential barriers to the successful adoption of sit-stand desks. This is the first study to comprehensively assess the health related effects of introducing standing desks for a short period of time in a school environment on body posture, anthropometric and cognitive abilities, physical activity, and sleep quality.

Aim

The purpose of this study is to investigate the effects of sit-stand desks on cognitive function, posture, and physical activity among primary school children. The research questions guiding this study are: 1) How does the use of sit-stand desks affect the distribution of static loads and spinal curvature in children? 2) What is the impact of sit-stand desks on reducing sedentary behavior and increasing physical activity during school hours? 3) Do sit-stand desks improve attention test scores in primary school children when tasks are performed standing versus sitting?

Material and methods

Study participants

Study group included 51 boys from football sport primary school in Rzeszów (Poland), aged 11-12 years (5 and 6 grade) the particular classes were chosen because they spend most of their lessons in one room, therefore the standing desks could be used in most of school time. Present study focuses on children in this age group since significant increases in sedentary time were observed between ages 9 and 12 years of age.[15]

Research design

In this non-randomized, interventional pilot study with cross-over design, convenience sample (feasible school infrastructure and the staff of the school, parents and children interested in participation) were used. Three data collection points were performed between March and May of 2025 – first one (T1) 4 weeks before introducing of standing desks to school environment, second measurement (T2) set directly before intervention start and third one (T3) after 4 weeks of intervention.

After consultation with teachers and the school principal, two classes were selected for the study. The parents or guardians of the children were sent an information letter with a consent form and all important details about the study intervention and methods, and an online meeting with the parents was organized to answer any questions. Children with parental informed consent were additionally required to provide verbal confirmation before any measurements were taken. Children and parents/guardians could withdraw from the study at any time without giving a reason. The study was conducted in accordance with ethical standards laid down in an appropriate version of the Declaration of Helsinki and has been approved by the Rector's Committee For The Ethics Of Scientific Research Involving Humans SGGW no. 4/RKE/2025/U. Children whose parents/guardians did not agree to participate or withdrew were still using the same classroom with standing desks and had the opportunity to use them if they wished but were not included in the measurement sets. Children were excluded from the project if they had an injury or illness that prevented them from attending class or from using standing desks.

Intervention

It was assumed that the participants would use the standing desks for approximately half of the lesson (the teacher was responsible for switching between the two types of desks). Consequently, one standing desk was provided for two children of similar body height. At the commencement of the first lesson, one participant utilised a standing desk, while the other employed a standard seated desk for approximately 20 minutes. Subsequently, the teacher requested that the students exchange their respective workstations. The children who had been engaged in standing for the latter half of the preceding lesson commenced the subsequent lesson with a seated desk. The option to revert to a standard desk was permitted at any point during the lesson.

Height-adjustable sit-stand desks were installed in classrooms adjacent to standard school desks, allowing for two children to utilise one standing desk for part of the lesson. This adjustment was necessary for a number of reasons. Firstly, it was not feasible to rapidly adjust the desks to various heights (a screwdriver was required), so children using one standing desk had similar heights. Secondly, it was important to allow children whose parents or guardians had not agreed or had withdrawn from the study to participate in lessons as usual. Thirdly, it was necessary to be able to return to a sitting position at any time, either at the child's request or at the teacher's discretion, depending on the specific tasks required in the lesson.

The initial phase of the study encompassed the initial set of measurements and the installation of standing desks in classrooms. Subsequently, the children continued with their lessons as usual for a period of four consecutive weeks, during which time they were unable to utilise the standing desks. Following this, a second set of measurements was conducted in accordance with the initial procedure. Thereafter, for a period of four weeks, the children whose parents had consented to participate were permitted to use the standing desks in accordance with the aforementioned protocol. Directly after the conclusion of the four-week intervention period, a third set of measurements was undertaken using the same protocol.

Anthropometry

Body weight and height (stretched stature) were measured in accordance with the ISAK protocol by an ISAK Level 3 anthropometrist. To assess stretched stature, a SECA stadiometer (model 217, SECA, Hamburg, Germany) was utilised. The participant was instructed to stand on the device barefoot and attempt to achieve the maximum height possible without lifting the heels from the base. A deep inhalation was then performed, and the measurement was taken at the point of maximum inhalation, recorded to the nearest 1 mm. This was done with the head positioned in Frankfurt plane and the moveable arm of the stadiometer in contact with the vertex anthropometric landmark.

Body composition

Body weight and composition were evaluated through the use of a bioelectrical impedance analysis (BIA), conducted with the aid of a body composition analyser device (BC-420 MA, Tanita, Tokyo, Japan). Body weight was assessed with an accuracy of 0.1 kg. Body mass index (BMI) was calculated according to the equation proposed by Quetelet: body mass (kg) divided by height squared (m^2) (kg/m^2). The BMI percentile of each participant was calculated using Polish age- and sex-specific BMI charts, based on the BMI values obtained.[16] In accordance with the criteria set forth by the Centers for Disease Control and Prevention, the percentiles for body mass index (BMI) in all subjects can be interpreted as indicative of normal body weight.[17] It was shown that BIA method is a reliable and accurate tool for the measurement of body composition in the paediatric population.[18] The children were instructed to stand barefoot on the device with light clothing. All measurements were taken in the morning (8:00–10:00). The children and parents/guardians of the participants were informed that they should refrain from engaging in strenuous exercise and excessive water intake for a minimum of eight hours prior to the measurement. The measurements were repeated in the following sets, always in the same hour and under the same conditions. For the purposes of the present study, the following body composition variables, estimated by the Tanita device, were analysed: body fat percentage (BFP), muscle mass (PMM) and total body water (TBW). The BFP percentage were found to yield normal values (BFP < 85th percentile and ≥ 2nd percentile) for the entire study group.[19]

Body posture analysis

The assessment of body posture was conducted using the KINEOD system (DMS Group, Gallargues-Le-Montueux, France), which enables the precise estimation of the angular values of the physiological curvatures of the spine in the sagittal plane. This is achieved through the 3D reconstruction of the posterior surface of the body, which is obtained through the use of depth cameras that acquire images using infrared. Prior to the examination, the requisite anthropometric landmarks were delineated on the child's back with the aid of a specialized hypoallergenic body marker (specifically, the C7 spinous process and multiple spinous processes in the thoracic and lumbar spine, the posterior superior iliac spines, and the inferior angles of the scapulae). Immediately following the examination, the identified points were removed using a solution of water and cleansing agent. The values of the lumbar lordosis and thoracic kyphosis angles of the examined children were estimated using dedicated software.

Foot static loads assessment

During the assessment of body posture, the subject was invited to stand freely on a tensometric platform (Free Med BASE, Sensor Medica, Guidonia Montecelio, Italy) in order to ascertain the static loads exerted on the feet during the subject's natural, unassisted stance. The device software calculated, among other variables, the maximum and mean pressure under each foot, expressed in g/cm^2. This was based on several seconds of data recording.

Physical activity, sedentary behavior and sleep

ActiGraph measurements were obtained over a continuous period of seven days and nights using the ActiGraph GT3X-BT monitor (ActiGraph, Pensacola, Florida, USA) and were subsequently analysed using the ActiLife 6.13 data analysis software. Actigraphy represents a valid alternative to polysomnography.[20] The device was positioned at the level of the right hip. Subjects were instructed to wear the monitor for a period of 24 hours per day, for a total of seven consecutive days and nights, during all activities, with the exception of those involving water. Parents or guardians were also provided with comprehensive instructions on how their children should utilise the activity monitor. Actigraphy data were collected at a sampling rate of 30 Hz, employing the Sadeh sleep algorithm.[21] The sleep parameters identified from the ActiGraphs were as follows: sleep efficiency (the percentage of time spent asleep during the sleep period), sleep duration (time from the child fell asleep until it woke up) and wake after sleep onset (WASO; refers to the number of minutes a child was awake between sleep onset and sleep offset).[22] After exclusion of the nocturnal sleep episode time, non-wear time was determined as 60 minutes of consecutive zeros allowing for 2 min of non-zero interruptions.[23] The time spent awake and the levels of physical activity were calculated and identified using data collected at 5-s intervals. A waking wear time of ≥ 500 minutes per day was employed as the criterion for a valid day, and ≥ 4 days were used as the criteria for a valid 7-day period of accumulated data (including ≥ 3 valid weekdays and ≥ 1 valid weekend day). For each participant, the mean minutes per day of moderate-to-vigorous physical activity (MVPA) and sedentary time were calculated. The cut-off points proposed by Evenson et al. were employed to ascertain the time spent engaged in sedentary (0-100 counts per minute) and MVPA (≥ 2296 counts per minute from all valid days). Furthermore, the number of steps taken was calculated.[24]

Cognitive test

The assessment of attention, concentration, ability to work under pressure, speed and accuracy of work was conducted and analysed by a licensed psychologist using the D2-R test. The test enables the assessment of various attention indicators, including perception, the number of errors committed, and the ability to perceive. It examines both continuous attention, which concerns the maintenance of active attention over a specified period of time, and selective attention, which pertains to the capacity to concentrate on selected stimuli. The test enables the assessment of the speed, quality and endurance of the individual being tested, as well as their ability to maintain focus over a short period of time. The test sheet comprises 14 lines, each containing 47 "d" or "p" leaders with varying combinations of lines beneath and/or above the letter. Each line comprises 21–22 letters that must be crossed out. The subject is allotted a specific time period for each line, with a maximum of 20 seconds. Once this time has elapsed, the subject must proceed to the subsequent line, regardless of whether they have completed the task for the previous line. The subject was required to identify and erase specific symbols from a set of similar ones within a specified time frame (20 seconds). The results of the test provide indicators that allow for the assessment of an individual's ability to concentrate, as well as their pace and accuracy of work. The D2-R questionnaire was administered on two occasions, once at a standard desk in a seated position and once at the same time the following day at a high desk in a standing position.

Stroop test

The efficiency of executive functions, specifically the ability to inhibit a habitual response and the ability to switch to a new, previously unused response criterion, was evaluated by a licensed psychologist using the Stroop test. The initial phase of the examination comprised ten lines of five words, representing colours (blue, green, yellow, red, brown, pink, black), inscribed in black font on a white card (an achromatic colour-word reading card). The second card differs from the first in that the same words are written in coloured font, but the colour of the font in which the words are written does not correspond to their meaning (a chromatic colour-word reading). In the third part of the test, the stimuli were presented as rows of coloured squares (a pure colour card). The subject was required to complete the following task: In the initial phase, participants were required to read the names of colours presented in black font (referred to as Card A). In the subsequent phase, they were instructed to read the names of colours while disregarding the colour of the font in which they were written (referred to as Card B). Finally, in the third phase, participants were asked to name the colour of the squares presented on the card (referred to as Card C). In the fourth part of the test, the subject was required to name the colour of the font in which the word was written, ignoring its meaning (card B).

Statistical analysis

The statistical analysis was conducted using the Statistica software (StatSoft, Tulsa, OK, USA). The assumption of normality was tested using the Shapiro-Wilk test. Continuous data are expressed median and interquartile range. The Wilcoxon paired test was employed to ascertain whether statistically significant differences existed in the parameters between data collection points. The Wilcoxon signed-rank (paired) test was selected because the study compared repeated measurements of the same participants across two data collection points. Preliminary analysis indicated that the assumptions required for parametric tests, particularly normal distribution of the differences, were not met. The Wilcoxon paired test is a non-parametric alternative that does not require normality and is therefore appropriate for analyzing paired, dependent samples.

Results

At the initial assessment, 51 included boys were 11.5±0.6 years of age, with 151.4±8.6 cm height and 40.1±8.1 kg weight (BMI: 17.3±2.2 kg/m^2). In general, children exhibit a greater body weight distribution on the left foot and a more pronounced kyphosis than lordosis. The majority of children adhere to the WHO recommendations for physical activity (at least 150 minutes of MVPA per week) and report an average of more than eight hours of good-quality sleep per day (with a sleep efficiency of more than 90% and a wake after sleep onset duration of less than 25 minutes). All the anthropometric, body posture, physical activity, sleep and cognitive skills parameters are listed in Table 1.

During the intervention period, statistically significant increases were observed for all anthropometric parameters, with the exception of FATP, where a significant decrease was noted. The analysis of the static loads under the feet of the subjects revealed a significant increase in both the mean and maximum loads under the right foot. This is particularly noteworthy given that subjects exhibited a tendency to place greater weight on the left foot. The observed change therefore appeared to result in a more balanced distribution of loads under the feet of the subjects. The only significant difference in spinal curvatures in the sagittal plane was the increase in the lordosis angle between the initial and mid-intervention measurements. Nevertheless, it proved difficult to identify any discernible linear trends in this parameters (Table 2).

A comparison of the data reveals significant variations in sedentary behaviour and light physical activity (PA) across the various measurement points. Specifically, a notable increase in sedentary behaviour was observed prior to the implementation of standing desks, subsequently followed by a decrease in sedentary behaviour post-introduction of standing desks. It should be noted that there has been a constant reduction in light PA. Furthermore, there was a substantial increase in vigorous physical activity (PA) prior to the intervention, and a notable rise in step count following the intervention. The study's participants who were provided with standing desks for a portion of their lessons exhibited a notable enhancement in their sleep efficiency after a four-week period (Table 3).

The results of the d2 test revealed significant improvements in all cognitive parameters, with the exception of the Percentage of Errors and the Fluctuation Rate when the test was completed in a standing position. Moreover, when the test was performed in a sitting position, a notable decline in the Percentage of Errors was observed between the first and second measurement points. Also, the Fluctuation Rate demonstrated a significant increase between the first and second measurements and a further increase between the first and third measurements when subjects were sitting. A significant improvement was observed in the Stroop test between

Table 1. Analysed parameters at T0 – before the standing desks introduction*

	Mean	Min.	Max.	Q1	Q3	SD
Anthropometry						
Age (n)	11.5	10.0	12.0	11.0	12.0	0.6
Height (cm)	151.4	132.3	170.6	146.5	156.0	8.6
Weight (kg)	40.1	28.6	62.6	35.3	43.9	8.1
BMI (kg/m²)	17.3	13.8	22.5	15.9	18.3	2.2
FATP (%)	12.8	5.5	25.3	9.6	14,2	4,7
PMM (kg)	33.0	23.4	50.1	29.5	35.6	6.0
TBW (kg)	25.5	18.2	38.6	22.8	27.5	4.6
Body posture						
Mean load LF (g/cm²)	258.0	193.0	370.0	230.0	284.0	43.5
Mean load RF (g/cm²)	203.5	154.0	263.0	179.0	230.0	31.0
Max load LF (g/cm²)	619.0	450.0	997.0	539.0	675.0	123.8
Max load RF (g/cm²)	537.3	358.0	776.0	470.0	590.0	102.5
Kifosis angle (°)	31.6	20.0	47.0	28.0	35.0	5.9
Lordosis angle (°)	17.3	0.0	37.0	3.0	26.0	11.9
Physical activity						
Sedentary (min)	7148.7	6430.0	8067.0	6895.5	7361.5	392.2
Light (min)	2367.3	1717.0	3091.0	2184.5	2589.0	336.0
Moderate (min)	374.3	123.0	643.0	302.5	445.0	112.6
Vigorous (min)	198.6	37.0	444.0	106.0	308.0	122.8
MVPA (min)	572.7	169.0	1069.0	433.0	717.5	204.9
Step Counts (n)	96344.7	50377.0	164193.0	80604.0	106931.5	23676.0
Sleep quality						
Average Sleep Efficiency	94.8	89.8	98.7	94.0	96.3	2.0
Average Total Sleep Time	490.0	335.6	623.8	435.5	543.3	71.4
WASO (min)	21.6	7.1	39.3	17.1	26.0	7.3
Cognitive skills						
Percentage of Errors SIT (%)	10.7	0.5	86.4	3.9	11.6	14.4
Percentage of Errors STN (%)	8.2	0.0	42.7	2.9	10.0	9.3
Concentration Performance SIT	148.6	83.0	198.0	133.5	161.5	23.2
Concentration Performance STN	179.0	115.0	256.0	156.0	198.5	31.0
The Fluctuation Rate SIT	6.4	2.0	12.0	5.0	8.0	2.3
The Fluctuation Rate STN	7.9	3.0	20.0	5.0	10.0	4.1
Total test effectiveness SIT	138.6	71.0	194.0	124.0	154.0	27.8
Total test effectiveness STN	168.9	98.0	253.0	146.0	194.0	35.3
Concentration index SIT	145.9	66.0	198.0	133.0	159.0	25.2
Concentration index STN	175.1	90.0	255.0	155.5	197.5	33.3
Stroop – time	27.8	16.0	51.0	22.0	32.5	8.3
Stroop – error corrected	0.9	0.0	4.0	0.0	1.5	1.1
Stroop – error noncorrected	0.1	0.0	2.0	0.0	0.0	0.4

* BMI – body mass index, Min. – minimum value, Max. – maximum value, Q1 – first quartile, Q3 – third quartile, SD – Standard Deviation, FATP – Fat Percentage, PMM – Muscle Mass, TBW – total body water, LF – left foot, RF – right foot, MVPA – moderate to vigorous physical activity, WASO – wake after sleep onset, SIT – sitting position, STN – standing position

Table 2. Analysed anthropometric parameters before (T1) during (T2) and after (T3) standing desks introduction*

	T1 Me (Q1–Q3)	T2 Me (Q1–Q3)	T3 Me (Q1–Q3)	p T1 vs T2	p T2 vs T3	p T1 vs T3
Anthropometry						
Height (cm)	150.2 (146.5–156)	150.3 (147–155.3)	151.0 (147–157)	0.001	<0.001	<0.001
Weight (kg)	38.0 (35.3–43.9)	38.2 (35.1–44.1)	39.5 (35.9–45.6)	<0.001	0.001	<0.001
BMI (kg/m²)	16.9 (15.9–18.3)	16.9 (16.2–18.5)	17.0 (16–18.7)	<0.001	0.722	<0.001
FATP (%)	12.5 (9.6–14.2)	11.8 (9.5–14.1)	11.1 (8.8–13.8)	0.003	<0.001	<0.001
PMM (kg)	31.6 (29.5–35.6)	32.1 (28.8–35.6)	33.3 (29.5–37.8)	<0.001	<0.001	<0.001
TBW (kg)	24.5 (22.8–27.5)	24.8 (22.3–27.5)	25.8 (22.8–29.2)	<0.001	<0.001	<0.001
Body posture						
Mean load LF (g/cm²)	245.0 (230–284)	255.0 (240–283)	242.0 (220.5–283.5)	0.336	0.288	0.057
Mean load RF (g/cm²)	198.0 (179–230)	211.0 (188–231)	209.5 (189.5–247)	0.071	0.379	0.001
Max load LF (g/cm²)	582.0 (539–675)	602.0 (543–689)	604.5 (538–717.5)	0.558	0.587	0.994
Max load RF (g/cm²)	529.0 (470–590)	543.0 (509–628)	540.5 (477–608.5)	0.073	0.965	0.032
Kifosis angle (°)	32.0 (28–35)	33.5 (28–37)	33.0 (28–37)	0.801	0.706	0.840
Lordosis angle (°)	19 (3–26)	25 (19–31)	21 (10–28)	0.013	0.186	0.253

* T1 – measurement before intervention, T2 – measurement during intervention, T3 – measurement after intervention, Me – median, Q1 – first quartile, Q3 – third quartile, p – statistical significance, BMI – body mass index, FATP – fat percentage, PMM – muscle mass, TBW – total body water, LF – left foot, RF – right foot, SIT – sitting position, STN – standing position

crease in lumbar lordosis after four weeks of sit–stand desk use. The lordosis increase of approximately 5–6° falls within the small-to-moderate ergonomic effect range reported by Cardon et al. and Clemes et al. This supports the interpretation that alternating sitting and standing can promote healthier spinal alignment without imposing excessive lumbar extension.[4,28] While the study's non-randomized design precludes strong inference, these findings strengthen previous evidence that postural variability (rather than prolonged standing per se) can be beneficial for musculoskeletal development in schoolchildren. The observed increase in the lordosis angle between initial and mid-intervention measurements are consistent with previous research that highlights the potential of sit-stand desks to improve postural health in children.[25,29]

Cognitive improvements

The results of the d2 and Stroop tests demonstrate significant cognitive improvements. Specifically, the d2

Table 3. Analysed physical activity and sleep quality parameters before (T1) during (T2) and after (T3) standing desks introduction*

	T1	T2	T3	p		
	Me (Q1–Q3)	Me (Q1–Q3)	Me (Q1–Q3)	T1 vs T2	T2 vs T3	T1 vs T3
Sedentary (min)	7180 (6977–7357)	7956 (7675–8260)	7547 (7118–7965)	<0.001	0.003	0,031
Light (min)	2279 (2171–2433)	1568 (1321–1720)	1408 (1041–1606)	<0.001	0.015	<0,001
Moderate (min)	358 (305–415)	323 (268–393)	338 (224–434)	0.050	0.660	0,037
Vigorous (min)	175 (120–415)	222 (167–309)	292 (179–462)	0.015	0.102	0,018
MVPA (min)	550 (417–692)	580 (436–666)	638 (403–876)	0.257	0.203	0,226
Step Counts (n)	98477 (80604–106932)	92387 (70608–107565)	109752 (74378–123647)	0.334	0.038	0,379
Average Sleep Efficiency	95 (94–96)	96 (94–97)	97 (95–97)	0.410	0.068	0,038
Average Total Sleep Time	504 (436–543)	487 (449–573)	490 (456–593)	0.494	0.068	0,274
WASO (min)	21 (17–26)	17 (12–27)	16 (12–23)	0.900	0.225	0,274

* T1 – measurement before intervention, T2 – measurement during intervention, T3 – measurement after intervention, Me – median, Q1 – first quartile, Q3 – third quartile, , p – statistical significance, MVPA – Moderate to Vigorous Physical Activity, WASO – Wake After Sleep Onset, SIT – sitting position, STN – standing position

Table 4. Analysed cognitive skills before (T1) during (T2) and after (T3) standing desks introduction*

	T1	T2	T3	T1 vs T2	T2 vs T3	T1 vs T3
D2–R test						
Percentage of Errors SIT (%)	7 (4–12)	6 (3–10)	6 (3–12)	0.028	0.992	0.373
Percentage of Errors STN (%)	5 (3–10)	6 (2–10)	6 (2–12)	0.695	0.345	0.854
Concentration Performance SIT	147 (134–162)	200 (175–231)	226 (196–256)	<0.001	<0.001	<0.001
Concentration Performance STN	176 (156–199)	219 (186–253)	231 (196–268)	<0.001	<0.001	<0.001
The Fluctuation Rate SIT	6 (5–8)	8 (6–10)	8 (5–10)	0.001	0.817	0.013
The Fluctuation Rate STN	7 (5–10)	8 (6–10)	8 (5–9)	0.809	0.169	0.498
Total test effectiveness SIT	139 (124–154)	193 (160–228)	218 (165–243)	<0.001	<0.001	<0.001
Total test effectiveness STN	170 (146–194)	202 (166–245)	220 (175–258)	<0.001	<0.001	<0.001
Concentration index SIT	144 (133–159)	199 (175–230)	224 (195–252)	<0.001	<0.001	<0.001
Concentration index STN	172 (156–198)	218 (177–243)	230 (191–266)	<0.001	<0.001	<0.001
Stroop test						
Stroop – time	26 (22–33)	25 (22–32)	22 (20–29)	0.786	<0.001	<0.001
Stroop – error corrected	1 (0–2)	1 (0–2)	0 (0–1)	0.840	<0.001	<0.001
Stroop – error noncorrected	0 (0–0)	0 (0–0)	0 (0–0)	0.361	0.593	0.345

* T1 – measurement before intervention, T2 – measurement during intervention, T3 – Measurement after intervention, Me – median, Q1 – first quartile, Q3 – third quartile, p – statistical significance, SIT – sitting position, STN – standing position

test revealed improvements in all cognitive parameters except for the percentage of errors and fluctuation rate when completed in a standing position. The drop in the percentage of errors and the increase in the fluctuation rate observed when the test was performed in a sitting position between the first and second measurements suggest that sitting may lead to decreased cognitive stability over time. It is necessary to consider the possible learning effects which could bias the observed results. This finding aligns with studies by Swartz et al., Mehta et al. and Wallace et al., which reported improved cognitive performance and attentiveness in students using sit-stand desks.[3,30,31] Our findings are corroborated by Van der Niet et al., who found that sedentary behavior adversely impacts cognitive function, while physical fitness improves executive and cognitive function in children, highlighting the importance to include executive functioning in research on physical activity and academic achievement correlation.[32]

The significant improvement observed in the Stroop test between the second and third assessment points regarding both time and corrected error occurrence could possibly supports the cognitive benefits of the intervention. The Stroop test measures cognitive control and the ability to manage competing information, suggesting that the desks may enhance these executive functions.[5,30] However, given that cognitive testing was not blinded and standing time was self-regulated by teachers, the observed effects should be interpreted as associations rather than causal improvements. Practice effects across repeated administrations of the d2-R and Stroop tasks may have contributed to incremental performance gains; nonetheless, the greater magnitude of change understanding conditions suggests additive effect of postural activation on attentional efficiency.

Clinical implications

The significant improvements in cognitive parameters, particularly in the standing position, suggest that sit-stand desks can be a valuable tool in creating dynamic and engaging learning environments. The study's results also extend the current findings,[2,6,30] which substantiate that physical activity imposed by interchangeable sitting and standing in class improves cognitive function in children.

Table 5. Comparison of D2 test performed in sitting and in standing position*

	T1	T2	T3
Percentage of Errors SIT (%)	7 (4–12)	6 (3–10)	6 (3–12)
Percentage of Errors STN (%)	5 (3–10)	6 (2–10)	6 (2–12)
p	0.009	0.363	0.790
Concentration Performance SIT	147 (134–162)	200 (175–231)	226 (196–256)
Concentration Performance STN	176 (156–199)	219 (186–253)	231 (196–268)
p	<0.001	0.049	0.019
The Fluctuation Rate SIT	6 (5–8)	8 (6–10)	8 (5–10)
The Fluctuation Rate STN	7 (5–10)	8 (6–10)	8 (5–9)
p	0.030	0.959	0.328
Total test effectiveness SIT	139 (124–154)	193 (160–228)	218 (165–243)
Total test effectiveness STN	170 (146–194)	202 (166–245)	220 (175–258)
p	<0.001	0.041	0.008
Concentration index SIT	144 (133–159)	199 (175–230)	224 (195–252)
Concentration index STN	172 (156–198)	218 (177–243)	230 (191–266)
	<0.001	0.092	0.003

* T1 – measurement before intervention, T2 – measurement during intervention, T3 – measurement after intervention, SIT – sitting position, STN – standing position

the second and third assessment points with regard to both time and corrected error occurrence (Table 4).

A comparison of the results of the d2-R test performed in a sitting and standing position revealed that all cognitive parameters exhibited significantly better performance when the children completed the test in a standing position during the initial set of measurements. Furthermore, in the second and third measurement sets, significant improvements in the standing position were noted in both Concentration Performance and Total Test Effectiveness. Additionally, at the third measurement point, a significantly higher Concentration Index was observed (Table 5). Since the study protocol assumed multiple cognitive tests on the same population, it is necessary to bear in mind the possible learning effects that could bias the observed results.

Discussion

Anthropometric changes

The study results indicate that during the intervention period, there were statistically significant increases in all anthropometric parameters, with the exception of FATP, which showed a significant decrease. This finding aligns with previous research indicating that increased physical activity and reduced sedentary behavior can positively impact body composition.[25] The notable decrease in FATP suggests that the introduction of sit-stand desks, by encouraging more movement and standing, is more likely to be associated with sedentary behavior reduction (which resonates with the conclusions made by Benden et al., Clemens et al. and Swartz et al., and healthier body composition in children.[4,26,27]

Postural analyses demonstrated a more symmetrical weight distribution between the feet and a moderate in-

Study limitations

While the current pilot study provides insights into the possible benefits of sit-stand desks, several methodological and contextual factors constrain interpretation. First, the study included only boys from a sports-oriented primary school, which limits generalizability to mixed-sex or less active populations. Second, the non-randomized crossover and absence of blinding introduce potential expectancy, Hawthorne, and teacher-influence effects. Third, actual standing duration was not objectively logged; therefore, the fidelity and "dose" of the intervention remain uncertain. Fourth, the presence of standing desks in classrooms during the pre-intervention phase may have altered behavior ("contamination"). Fifthly, the crossover nature of the study necessitated repeated cognitive testing, which could have yielded learning effects. Therefore, any observed improvements may be partly due to familiarity with the tests. Finally, academic performance and psychosocial variables (motivation, enjoyment, fatigue) were not measured, leaving the educational implications incomplete.

Therefore, certain gaps remain that encourage further investigation. The long-term effects of sit-stand desk interventions on cognitive and academic outcomes need to be explored through longitudinal studies. Additionally, more research is needed to understand the differential impact of sit-stand desks on various student populations. Future studies should also investigate the optimal duration and frequency of standing periods to maximize cognitive benefits without causing fatigue or discomfort. Additionally, exploring the combined effects of sit-stand desks with other physical activity interventions, such as short activity breaks, could provide a more comprehensive understanding of how to best reduce sedentary behavior and enhance cognitive performance in educational settings. The combination of both quantitative and qualitative research designs (with an emphasis on the latter one, such as teachers' and students' perspective on the feasibility of sit-stand desk integration into classroom settings, as highlighted in Erwin et al. is seen as essential for the holistic approach to the studied intervention.[11]

Conclusions

This pilot study's findings demonstrate positive effects of integrating sit-stand desks into primary school classrooms. By allowing children to alternate between sitting and standing during cognitive tasks, improvements were observed in physical distribution, spinal curvature, and cognitive performance. This research contributes to a growing body of evidence supporting the adoption of dynamic workstations in educational settings to address both physical and cognitive challenges associated with prolonged sedentary behavior.

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Declarations

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Author contributions

Conceptualization, P.M. and L.M.; Methodology, P.M. and J.H.; Software, P.M.; Validation, P.M., L.M. and J.H.; Formal Analysis, P.M.; Investigation, P.M., L.M. and J.H.; Resources, J.H.; Data Curation, P.M.; Writing – Original Draft Preparation, P.M. and L.M.; Writing – Review & Editing, P.M. and L.M.; Visualization, J.H.; Supervision, L.M.; Project Administration, P.M.; Funding Acquisition, P.M.

Conflicts of interest

The authors declare that they have no competing interests.

Data availability

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

Ethics approval

The study was approved by the Ethics Committee (Resolution No. 4/RKE/2025/U, dated 7.03.2025) and conducted in accordance with the Declaration of Helsinki.

References

1. Tremblay MS, LeBlanc AG, Kho ME, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth. *Int J Behav Nutr Phys Act*. 2011;8(1):98. doi:10.1186/1479-5868-8-98
2. Wick K, Faude O, Manes S, Zahner L, Donath L. I Can Stand Learning: A Controlled Pilot Intervention Study on the Effects of Increased Standing Time on Cognitive Function in Primary School Children. *Int J Environ Res Public Health*. 2018;15(2):356. doi:10.3390/ijerph15020356
3. Swartz AM, Tokarek NR, Strath SJ, Lisdahl KM, Cho CC. Attentiveness and Fidgeting While Using a Stand-Biased Desk in Elementary School Children. *Int J Environ Res Public Health*. 2020;17(11):3976. doi:10.3390/ijerph17113976
4. Clemes SA, Barber SE, Bingham DD, et al. Reducing children's classroom sitting time using sit-to-stand desks: findings from pilot studies in UK and Australian primary schools. *J Public Health (Bangkok)*. 2016;38(3):526-533. doi:10.1093/pubmed/fdv084
5. Donnelly JE, Hillman CH, Castelli D, et al. Physical Activity, Fitness, Cognitive Function, and Academic Achievement in Children: A Systematic Review. *Med Sci Sport Exerc*. 2016;48(6).
6. Guirado T, Chambonnière C, Chaput J-P, Metz L, Thivel D, Duclos M. Effects of Classroom Active Desks on Children and Adolescents' Physical Activity, Sedentary Behavior, Academic Achievements and Overall Health: A Systematic Review. *Int J Environ Res Public Health*. 2021;18(6). doi:10.3390/ijerph18062828
7. Visier-Alfonso ME, Sánchez-López M, Bizzozero-Peroni B, et al. The impact and perceptions of standing desk interventions on movement patterns and physical, mental, and academic outcomes in university students: a scoping review. *BMC Public Health*. 2025;25(1):1726. doi:10.1186/s12889-025-22912-z
8. Sherry AP, Pearson N, Ridgers ND, et al. Impacts of a Standing Desk Intervention within an English Primary School Classroom: A Pilot Controlled Trial. *Int J Environ Res Public Health*. 2020;17(19). doi:10.3390/ijerph17197048
9. Hinckson E, Salmon J, Benden M, et al. Standing Classrooms: Research and Lessons Learned from Around the World. *Sport Med*. 2016;46(7):977-987. doi:10.1007/s40279-015-0436-2
10. Silva DR, Minderico CS, Pinto F, Collings PJ, Cyrino ES, Sardinha LB. Impact of a classroom standing desk intervention on daily objectively measured sedentary behavior and physical activity in youth. *J Sci Med Sport*. 2018;21(9):919-924. doi:10.1016/j.jsams.2018.01.007
11. Erwin H, Beighle A, Routen A, Montemayor B. Perceptions of Using Sit-to-Stand Desks in a Middle School Classroom. *Health Promot Pract*. 2017;19(1):68-74. doi:10.1177/1524839917730046
12. Sherry AP, Pearson N, Clemes SA. The effects of standing desks within the school classroom: A systematic review. *Prev Med Reports*. 2016;3:338-347. doi:10.1016/j.pmedr.2016.03.016
13. Haq IU, Mohiz A, Spadafora G, et al. The Role of Network of Extended Reality-Enabled Laboratories in Enhancing STEM Education: Bridging Theory and Practice in the Digital Classroom BT - Proceedings of I4SDG Workshop 2025 - IFToMM for Sustainable Development Goals. In: Carbone G, Quaglia G, eds. Cham: Springer Nature Switzerland; 2025:362-372.
14. Jan A, Ul Haq I, Anas M, Husnain G, Ahmad W. Development and evaluation of a novel force myography (FMG) based human-machine interface for transradial prosthetics: A comparative study with electromyography (EMG) techniques. *Mehran Univ Res J Eng Technol*. 2024;43(4):55-62. doi:10.22581/muet1982.2948
15. Janssen X, Mann KD, Basterfield L, et al. Development of sedentary behavior across childhood and adolescence: longitudinal analysis of the Gateshead Millennium Study. *Int J Behav Nutr Phys Act*. 2016;13(1):88. doi:10.1186/s12966-016-0413-7

16. Kułaga Z, Różdżyńska-Świątkowska A, Grajda A, et al. Percentile charts for growth and nutritional status assessment in Polish children and adolescents from birth to 18 year of age. *Stand Med*. 2015;12(1):119-135.
17. Barlow SE. Expert Committee Recommendations Regarding the Prevention, Assessment, and Treatment of Child and Adolescent Overweight and Obesity: Summary Report. *Pediatrics*. 2007;120(Supplement 4):S164 LP-S192. doi:10.1542/peds.2007-2329C
18. Tyrrell VJ, Richards G, Hofman P, Gillies GF, Robinson E, Cutfield WS. Foot-to-foot bioelectrical impedance analysis: a valuable tool for the measurement of body composition in children. *Int J Obes*. 2001;25(2):273-278. doi:10.1038/sj.ijo.0801531
19. McCarthy HD, Cole TJ, Fry T, Jebb SA, Prentice AM. Body fat reference curves for children. *Int J Obes*. 2006;30(4):598-602. doi:10.1038/sj.ijo.0803232
20. Sadeh A. The role and validity of actigraphy in sleep medicine: An update. *Sleep Med Rev*. 2011;15(4):259-267. doi: 10.1016/j.smrv.2010.10.001
21. Acebo C, Sadeh A, Seifer R, et al. Estimating Sleep Patterns with Activity Monitoring in Children and Adolescents: How Many Nights Are Necessary for Reliable Measures? *Sleep*. 1999;22(1):95-103. doi:10.1093/sleep/22.1.95
22. ActiGraph. ActiLife 6 User's Manual, Version 9.0.0. https://s3.amazonaws.com/actigraphcorp.com/wp-content/uploads/2018/02/22094137/SFT12DOC13-ActiLife-6-Users-Manual-Rev-A-110315.pdf. Published 2012. Accessed October 6, 2022.
23. Troiano RP, Berrigan D, Dodd KW, et al. Physical activity in the united states measured by accelerometer: comment. *Med Sci Sport Exerc*. 2008;40(6).
24. Evenson KR, Catellier DJ, Gill K, Ondrak KS, McMurray RG. Calibration of two objective measures of physical activity for children. *J Sports Sci*. 2008;26(14):1557-1565. doi: 10.1080/02640410802334196
25. Hinckson EA, Aminian S, Ikeda E, et al. Acceptability of standing workstations in elementary schools: A pilot study. *Prev Med (Baltim)*. 2013;56(1):82-85. doi: 10.1016/j.ypmed.2012.10.014
26. Benden ME, Zhao H, Jeffrey CE, Wendel ML, Blake JJ. The Evaluation of the Impact of a Stand-Biased Desk on Energy Expenditure and Physical Activity for Elementary School Students. *Int J Environ Res Public Health*. 2014;11(9):9361-9375. doi:10.3390/ijerph110909361
27. Swartz AM, Tokarek NR, Lisdahl K, Maeda H, Strath SJ, Cho CC. Do Stand-Biased Desks in the Classroom Change School-Time Activity and Sedentary Behavior? *Int J Environ Res Public Health*. 2019;16(6). doi:10.3390/ijerph16060933
28. Cardon G, De Clercq D, De Bourdeaudhuij I, Breithecker D. Sitting habits in elementary schoolchildren: a traditional versus a "Moving school." *Patient Educ Couns*. 2004;54(2):133-142. doi:10.1016/S0738-3991(03)00215-5
29. Donnelly JE, Lambourne K. Classroom-based physical activity, cognition, and academic achievement. *Prev Med (Baltim)*. 2011;52:S36-S42. doi: 10.1016/j.ypmed.2011.01.021
30. Mehta RK, Shortz AE, Benden ME. Standing Up for Learning: A Pilot Investigation on the Neurocognitive Benefits of Stand-Biased School Desks. *Int J Environ Res Public Health*. 2016;13(1):ijerph13010059. doi:10.3390/ijerph13010059
31. Wallace AL, Swartz AM, Cho CC, Kaiver CM, Sullivan RM, Lisdahl KM. Stand-Biased Desks Impact on Cognition in Elementary Students Using a Within-Classroom Crossover Design. *Int J Environ Res Public Health*. 2022;19(9):5684. doi:10.3390/ijerph19095684
32. van der Niet AG, Hartman E, Smith J, Visscher C. Modeling relationships between physical fitness, executive functioning, and academic achievement in primary school children. *Psychol Sport Exerc*. 2014;15(4):319-325. doi: 10.1016/j.psychsport.2014.02.010