STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Line number
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **The load of school backpacks and postural stability in children with abnormal body weight – do the WHO recommendations need to be changed? A cross sectional study.**	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found The aim of the study was to determine how the load of a school backpack affects postural stability in children with different body weight deviations (underweight, overweight, obesity) and to assess the validity of modifying current recommendations regarding acceptable backpack weight. The study involved 235 early school-age children, divided into groups based on body weight, including a control group with normal body weight. The stabilometrics measurements were conducted under conditions with and without the backpack load. The results showed that children with obesity experienced a significant deterioration in postural stability when carrying a backpack, particularly in tests conducted with open and closed eyes. Children with underweight achieved results comparable to the control group. It was found that current recommendations on acceptable backpack weight (as a percentage of body weight) do not account for the specific needs of children with overweight and obesity, who are already dealing with musculoskeletal system overload. The findings suggest a need to revise the percentage values for backpack load or introduce systemic solutions for this group of children.	10-32
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported The issue of overloaded school backpacks remains unresolved. Numerous studies address the normative weight values for backpacks. These studies recommend a load ranging from 10% to 25% of the child's body weight, depending on the region or country. However, there is no global consensus on the weight limit for backpacks, with the most commonly cited limit being up to 15%. The numerous authors point to the negative effects of carrying a load, such as forward body tilt, and spine issues, although in the latter case, there are many confounding factors that may influence the occurrence of these issues, and the studies are observational. Few studies evaluate stabilometrics parameters under the load of a school backpack, which seem to be one of the key factors in postural stability disturbances. Postural stability control is an integral part of every motor task, with particular emphasis on complex tasks, and its peak development occurs at a younger age. Postural control depends on expanding the limits of stability, influencing strategies. However, how the additional weight generated by a school backpack affects stabilometrics parameters in children remains unanswered in the literature. Research in this area is lacking. However, how the additional weight generated by a school backpack affects stabilometrics parameters in children remains unanswered in the literature. Research in this area is lacking. Moreover, none of the existing studies on backpack weight include children with abnormal body weight. When analysing children with underweight, overweight, and obesity, who are subject to the same backpack weight standards, we cannot be certain whether the recommended loads are appropriate. Overweight and obese children, according to current recommendations, are allowed to carry a heavier school backpack, which, given their skeletal system's burden with excess body mass, is already harmful even without the additional weight of a backpack. Underweight children, on the other hand, must carry a lighter backpack despite having the same lessons on a given day, which may make it difficult to meet this criterion, exposing underweight children to overload of the musculoskeletal system.	38-79
Objectives	3	State specific objectives, including any prespecified hypotheses The authors of this study, based on empirical research, clearly state that when selecting the weight of a school backpack, a broader perspective should be taken to assess how the load is distributed across the support base and whether the additional weight on the child's back affects postural stability, which plays a key role in developing proper body posture. Based on the gap in the evidence-based litera-	74-80

ture, the aim of this study was to examine the average actual percentage ratio of the backpack weight to the body weight of children with abnormal body mass in relation to the recommended normative values. Additionally, the study investigated how stabilographic parameters change under the influence of an external load, such as a school backpack, and whether there is a need to revise recommendations regarding the permissible backpack load for children with abnormal body mass.

Predefined hypotheses:

1. Current recommendations regarding allowable backpack weight (10-15% of body weight) are insufficient to address the needs of overweight and obese children.
2. Overweight and obese children show worse stabilometrics parameters compared to children with normal weight, especially when wearing a backpack.
3. Underweight children may be at greater risk of strain associated with wearing backpacks that are within the weight range recommended by current guidelines.
4. There is a need to develop more individualized backpack load standards for children with abnormal body weight.

Methods			
Study design	4	Present key elements of study design early in the paper The study was cross-sectional and observational, conducted in a group of early school-aged children. It assessed the impact of backpack load on the postural stability of children across different weight categories (underweight, overweight, obesity) compared to children with normal body weight. The main stabilometrics parameters were measured under conditions with and without a backpack, in tests with eyes open and closed.	2, 85, 155-158
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection The study was conducted in schools in the Silesian Voivodeship, Poland. Participant recruitment was preceded by obtaining written consent from parents/legal guardians, in accordance with the guidelines of the Helsinki Declaration. Eligibility criteria included the absence of significant postural defects, spinal deformities or musculoskeletal injuries in the period of 3 months prior to the study. The measurements were taken in the morning hours, taking into account the full load of the backpacks according to the schedule of classes of the day. The analysis included, among others, measuring the backpack mass, calculating its percentage ratio to the child's body mass and stabilometric assessments using the Zebris PDM platform. **Key elements:** 1. **Study group**: 235 children aged 7-9 years, divided into groups according to body weight: underweight (n=49), overweight (n=48), obese (n=33) and normal body weight (n=105). 2. **Backpack weight measurement**: Tared medical scale, morning measurement. Calculation of the backpack weight to body weight ratio (%). 3. **Stabilometric tests**: In static conditions (standing upright, without shoes, arms along the body). Measurements with and without a backpack, with open and closed eyes, performed three times on the Zebris PDM platform. 4. **Statistical analyses**: Student's t-test, Wilcoxon signed-rank tests and linear regression were performed to assess the effect of backpack load on stabilometric parameters in different body mass groups.	86-90; 94-136

Participants	6	a) Give the eligibility criteria, and the sources and methods of selection of participants **Eligibility criteria:** **Inclusion in the study:** 1. Children aged 7–9 attending primary schools in the Silesian Voivodeship, Poland. 2. No significant postural defects (e.g. scoliosis, Scheuermann's disease) or spinal deformities. 3. No lower limb injuries or other musculoskeletal injuries in the 3 months prior to the examination. 4. No significant visual or hearing impairments. 5. No significant differences in lower limb length or need for wearing orthopedic insoles. **Exclusion from the study:** 1. Children with serious spinal deformities or diagnosed postural defects. 2. Children with musculoskeletal disorders, infections or injuries that prevent participation in the study. 3. Children from sports classes and with incomplete data or lack of consent from parents/legal guardians. **Sources and methods of participant selection:** 1. **Recruitment** : Invitations to participate in the study were sent to 1,600 randomly selected early school-age children. 2. **Verification of consent** : Written consent from parents/guardians was required before the study began. Of the 987 consents, cases were excluded if complete documentation was missing or if both parents did not sign when legally required. 3. **Posture assessment** : Participants underwent a posture assessment to exclude children with visible postural defects. 4. **Division into groups** : Based on the BMI index (calculated according to WHO guidelines), the children were divided into four groups: – Underweight (n=49) – Normal body weight (n=105) – Overweight (n=48) – Obesity (n=33). **Number of participants:** The sample size was calculated using G*Power 3.1 software, assuming a significance level of $\alpha = 0.05$, 95% test power, and a medium effect size of 0.25, indicating a representative group of 280 subjects. A loss and data incompleteness rate of 20% was accounted for during the main study (assessment of stabilometric parameters).The final analysis included 235 children who met the eligibility criteria and had complete stabilometric data.	94-136
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **1. Results (outcomes):** stabilometric parameters measured under static conditions: – **SPL (sway path length):** Length of the centre of pressure movement path. – **WoE (width of the ellipse):** Width of the ellipse describing postural stability. – **HoE (height of the ellipse):** Height of the ellipse describing postural stability. – **AoE (area of the ellipse):** The area of the ellipse describing postural stability. – **BWD (body weight distribution):** The balance of body weight distribution between the right and left sides. Results were measured under two conditions: – Without a backpack – With a backpack. In both cases, tests were performed with eyes open and closed.	123-137 144-150 153-165

2. **Exposures:**
- **Backpack Weight (SW):** The weight of the backpack measured in kilograms.
- **Percentage of backpack weight to body weight (%SW):** Calculated as the ratio of backpack weight to the child's body weight.

3. **Predictors:**
- **Body Mass Index (BMI):** Calculated based on a child's weight and height, and classified into categories: underweight, normal weight, overweight, obese.
- **Body Mass Group:** Category of the child based on BMI (underweight, normal weight, overweight, obese).

4. **Potential confounding factors:**
- **Child age:** All children were aged 7–9 years to minimise developmental differences.
- **Gender:** Differences in outcomes between girls and boys were examined.
- **Physical activity level:** May influence stabilometric results, although it was not directly measured in the study.
- **School schedule:** May have influenced the weight of your backpack on a given day.

5. **Effect modifiers (effect modifiers):**
- **Musculoskeletal condition:** Children with postural defects or injuries were excluded, but individual differences in musculoskeletal condition may have influenced the results.
- **Backpack load:** The percentage of backpack mass relative to body mass (low vs. high) may have modified the effect of load on postural stability.
- **Sensory status:** Eyes-closed testing accounted for differences in the use of proprioception in postural control.

These variables allowed for a comprehensive analysis of the influence of backpack load on children's postural stability depending on body weight and other factors.

Diagnostic criteria

The following diagnostic criteria were used in the study:

1. **Body mass index (BMI):**

Body mass index (BMI) was calculated as body weight in kilograms divided by the square of height in meters (kg/m^2). Children were classified according to the WHO criteria:

- **Underweight:** BMI z- score < -1.0 SD.
- **Normal body weight:** BMI z- score between -1.0 SD and +1.0 SD.
- **Overweight:** BMI z- score > +1.0 SD.
- **Obesity:** BMI z- score > +2.0 SD.

Body weight was measured using a calibrated medical scale with an accuracy of 0.1 kg, and height was measured using a stadiometer with an accuracy of 0.1 cm. Data were analysed based on percentile charts for the Polish children population (Ola and Olaf, PL).

2. **Stabilometric criteria:**

Zebris PDM platform was used to assess postural stability and measured balance parameters such as:

- Centre of Pressure Path Length (SPL).
- Width and height of the stability ellipse (WoE , HoE).
- Body weight distribution between sides (BWD).

Tests were performed in two conditions (with and without a backpack) and with eyes open and closed. Each test was repeated three times, and the average values of these repetitions were used for analysis.

3. **Backpack load standards:**

		The normative backpack load was set at 10-15% of the child's body weight, in accordance with the guidelines of the Chief Sanitary Inspectorate (GIS) and WHO. Backpacks exceeding this limit were classified as overloaded. 4. **Exclusion of children with postural defects:** Children with significant spinal deformities, such as scoliosis or Scheuermann's disease, were excluded based on an initial postural assessment performed by a qualified physiotherapist. These criteria ensured a uniform and precise assessment of participants and enabled comparison of results between groups.	
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **1. Body weight (BMI) and height:** – **Data source:** Data on children's weight and height were obtained from direct measurements conducted by the researchers. – **Evaluation methods:** **Body weight:** Measured using a calibrated medical scale (accurate to 0.1 kg). **Height:** Measured using a height measuring rod accurate to 0.1 cm (Tanita DC-430MA). – **Comparability of assessment methods:** Measurement of body weight and height was uniform for all study participants, regardless of group (underweight, normal weight, overweight, obese), which ensures comparability of results. **2. Backpack weight:** – **Data source:** Backpack weight was measured using Tared medical scales that provided measurement accuracy to within 0.1 kg. – **Evaluation methods:** **Backpack weight:** Backpack weighing was conducted in the morning before classes started, when children had full backpacks according to the schedule for that day. **Percentage of backpack weight to body weight:** The ratio of backpack weight to body weight was calculated to assess whether the backpack was within the normal range (10–15% of body weight) or overloaded. – **Comparability of assessment methods:** Backpack weighing was uniform for all groups and the calculation of the percentage of backpack load was related to the actual body weight of the participants. **3. Stabilometric parameters:** – **Data source:** Data on postural stability came from measurements performed using the Zebris PDM platform (Isny , Germany), which assessed parameters of balance and postural stability. – **Evaluation methods:** **Stabilometric tests:** Children performed the tests in a standing position (no shoes, arms along the body), in two conditions: ▪ **Without a backpack** and ▪ **With a backpack** (worn symmetrically on both shoulders). **Types of tests:** Measurements were performed in two sensory conditions: with **eyes open** and with **eyes closed.** o **Evaluated parameters:** ▪ **SPL (sway path length)** – the length of the path of movement of the center of pressure. ▪ **WoE (width of the ellipse)** – width of the ellipse. ▪ **HoE (height of the ellipse)** – height of the ellipse. ▪ **AoE (area of the ellipse)** – surface of the ellipse. ▪ **BWD (body weight distribution)** – distribution of body weight between the right and left sides. – **Comparability of evaluation methods:** o Stabilometric tests were performed under the same conditions for all participants, except for the backpack load, which en-	123-137 144-150 153-165

		sured comparability of data. o Differences in postural stability scores between groups (underweight, normal weight, overweight, obese) were assessed based on changes in stabilometric parameters with and without a backpack. o Additionally, eyes-closed tests allowed us to assess proprioceptive mechanisms in postural control. **4. Confounding factors:** – **Data sources:** Potential confounding factors such as age, gender, physical activity level was taken into account in statistical analyses. – **Assessment Methods:** Age and gender were determined based on participant demographics. Physical activity level was not directly measured in the study, but differences in school schedules that could affect backpack weight were taken into account. All assessment methods were standardized and comparable between groups, ensuring the reliability of the results and enabling their comparison in the context of the influence of backpack load on the postural stability of children with different body weight categories.	
Bias	9	Describe any efforts to address potential sources of bias **Efforts to address potential sources of bias:** The study took a number of steps to minimize potential sources of bias that could affect the results: – **Participant selection:** In order to ensure the representativeness of the sample, participants were randomly recruited from different schools in the Silesian Voivodeship, and children with severe postural defects, musculoskeletal injuries, vision or hearing problems were excluded. Additionally, children from sports classes were also excluded to avoid the influence of specialized training programs on the results. – **Control of confounding variables:** Potential confounding variables such as age, gender, physical activity level, and school schedule were identified and controlled for. Statistical analyses included these variables to ensure that differences between groups were due to body weight and not other factors. – **Accuracy of measurements:** All measurements, such as body weight, height, backpack weight and stabilometric parameters , were performed using appropriately calibrated medical devices (medical scale, stadiometer, Zebris PDM platform), which minimized the risk of measurement errors. – **Participant consent:** Participation in the study was voluntary, and written consent was obtained from parents or legal guardians before the study began. Only children who met the eligibility criteria were allowed to participate in the study to eliminate biases related to inappropriate participants.	105-113 131-133 152-159 86-91
Study size	10	Explain how the study size was arrived at The sample size was determined based on statistical power analysis to ensure sufficient power to detect significant differences between groups. Details of study sizing: – **Power analysis:** Sample size was calculated using G*Power 3.1, assuming a significance level of $\alpha = 0.05$, a power of 95%, and a medium effect size (0.25). This resulted in a representative sample of 280 children. – **Taking into account data loss:** Due to possible data loss (e.g. missing measurements or incomplete consents), a data loss of 20% was assumed. Therefore, recruitment of 1600 children was planned, of which 235 children were finally qualified for the study after meeting all eligibility criteria. The sample size was planned to provide adequate statistical power to detect differences between groups of children with different body weight categories (underweight, normal weight, overweight, obese) and to analyze the effect of backpack load on postural stability.	95-123
Quantitative varia-	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why In the study, quantitative variables were handled in several ways, depending on the type of data and the purpose of the analysis:	123-137

bles		**1. Body weight and height (BMI):** – **Analysis methods:** Body mass index (BMI) was calculated based on body weight and height. Children were classified into appropriate groups (underweight, normal weight, overweight, obese) based on BMI z-scores , according to WHO guidelines. – **Grouping:** o **Underweight:** BMI z- score < -1.0 SD. o **Normal body weight:** BMI z- score between -1.0 SD and +1.0 SD. o **Overweight:** BMI z- score > +1.0 SD. o **Obesity:** BMI z- score > +2.0 SD. These variables were treated as quantitative variables and analyzed in the context of their influence on stabilometric parameters (e.g. postural balance). **2. Backpack weight:** – **Analysis Methods:** Backpack weight was measured using standard medical scales, and the percentage of backpack weight relative to child body weight was calculated as a quantitative variable (%SW). – **Grouping:** Two categories of backpacks have been established: o **Backpacks in the norm:** Backpack load within 10-15% of the child's body weight. o **Overloaded backpacks:** Backpack load exceeding 15% of body weight. Analysis of this variable allowed for the assessment of how backpack load affects postural stability in different groups of children. **1. Stabilometric parameters (SPL, WoE, HoE, AoE, BWD):** – **Analysis methods: All** stabilometric parameters, such as center of pressure path length (SPL), ellipse width (WoE), ellipse height (HoE), ellipse area (AoE), and body weight distribution (BWD), were treated as quantitative variables and analysed using descriptive statistics (mean, standard deviation) and statistical tests. – **Grouping:** Stabilometric parameters were analysed depending on: o **Presence of a backpack (with a backpack vs. without a backpack)** o **BMI groups** (underweight, normal weight, overweight, obese). Variability in stabilometric results was assessed in the context of backpack load and BMI category to examine how these factors affect postural balance.	145-151 154-167
Statistical methods	12	a) Describe all statistical methods, including those used to control for confounding Statistical analyses were carried out using the Excel and Statistics 13v programs. Descriptive statistics of the studied parameters - medians (Me), means (X), standard deviations (SD). Non-parametric statistics were used for intergroup comparisons: the Man-Whitney U test for two groups and Kruskal-Wallis ANOVA - when there were more groups. Multiple comparisons were performed using the Tukey's *p*-value. Missing data analysis and collinearity diagnostics were conducted before the analyses. The assumed level of statistical significance: $p<0.05$. Homogeneity of variance was verified with the F-test, F-Snedecor test. The Shapiro Wilk test was used to evaluate the normal distribution. To assess changes in stabilometrics parameters, the student's t-test and the Wilcoxon signed-rank test were used. Linear regression models were then used to explore how each of the predictors were associated with the stabilometrics parameters. The correlation was calculated using Pearson's R and R-Spearman when the distribution was not considered to be normal.	170-181
		(*b*) Describe any methods used to examine subgroups and interactions **Correlations between variables:** – Within each BMI group, correlation analyses (Pearson for normal data and Spearman for non-normal data) were performed to examine how backpack weight (%SW) and other quantitative variables (e.g., body mass) were associated with stabilometric pa-	170-181

		rameters. – These correlations were examined separately within each BMI group to determine whether interactions between variables varied by child weight category. **Multiple group tests:** – **Kruskal-Wallis ANOVA:** For non-normal variables, Kruskal- Wallis analysis was used to compare stabilometric parameters between more than two BMI groups (underweight, normal weight, overweight, obese), both with and without a backpack. This analysis allowed for the assessment of differences between groups where the data were not normally distributed.	
		(*c*) Explain how missing data were addressed **Solution to the missing data problem** In this study, the problem of missing data was addressed using appropriate imputation and analysis methods to minimize the impact of missing values on the study results. **1. Removing cases with missing data:** – First, data that were incomplete or contained errors (e.g., measurement artifacts) were removed from the analysis. Ultimately, data from 235 children were included in the analysis, representing approximately 80% of the initial sample (including a planned 20% loss of data due to missing responses or incomplete measures). – Children who had incomplete data on basic measurements (e.g., body weight, height, backpack weight) or were unable to participate in the full testing process (e.g., no signed consent forms) were excluded from the analysis. **2. Assumed data loss:** At the beginning of the study, a maximum loss of data of 20% was assumed, which corresponded to the expected number of children who might be excluded due to incomplete responses or measurement errors. By using appropriate data imputation and selection methods, the total amount of data available for analysis was sufficient to obtain reliable and accurate results.	100-122 116-120
		(*d*) If applicable, describe analytical methods taking account of sampling strategy The sample size was calculated using G*Power 3.1 software, assuming a significance level of $\alpha = 0.05$, 95% test power, and a medium effect size of 0.25	96-98
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	a)Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **Number of people at each stage of the study:** ● **Potentially eligible individuals:** ○ **1,600 children** aged 7–9, randomly selected from various primary schools in the Silesian Voivodeship, were invited to participate in the study. ● **Individuals screened for eligibility:** ○ Of the 1,600 invited children, **987 families** agreed to participate in the study and their children underwent initial qualification tests. ● **Individuals confirmed as eligible:**	100-124

- After the initial assessment (including posture assessment), of the above-mentioned 987 children, **294** met all the eligibility criteria, such as the absence of postural defects, lower limb injuries, spine deformities and other excluding diseases.

- **People included in the study:**
    - After excluding children with significant postural defects and others not meeting the criteria, **235 children** (mean age: 7.9 ± 0.74) were included in the main analysis. These children were divided into groups according to BMI categories (underweight, normal weight, overweight, obese).
- **People completing observation:**
    - During the study, **5 children** voluntarily withdrew from the study. The remaining children completed the observation according to the study protocol.
- **Persons analysed:**
    - The final analysis included **235 children** who had complete data and completed the study, including data on stabilometric tests (with and without a backpack), body weight, height, and backpack weight.

In summary, 1600 children were initially invited, of whom 294 were considered eligible after initial screening. After excluding cases that did not meet the criteria, 235 children were included in the analysis, completed the follow-up, and were included in the final analysis.

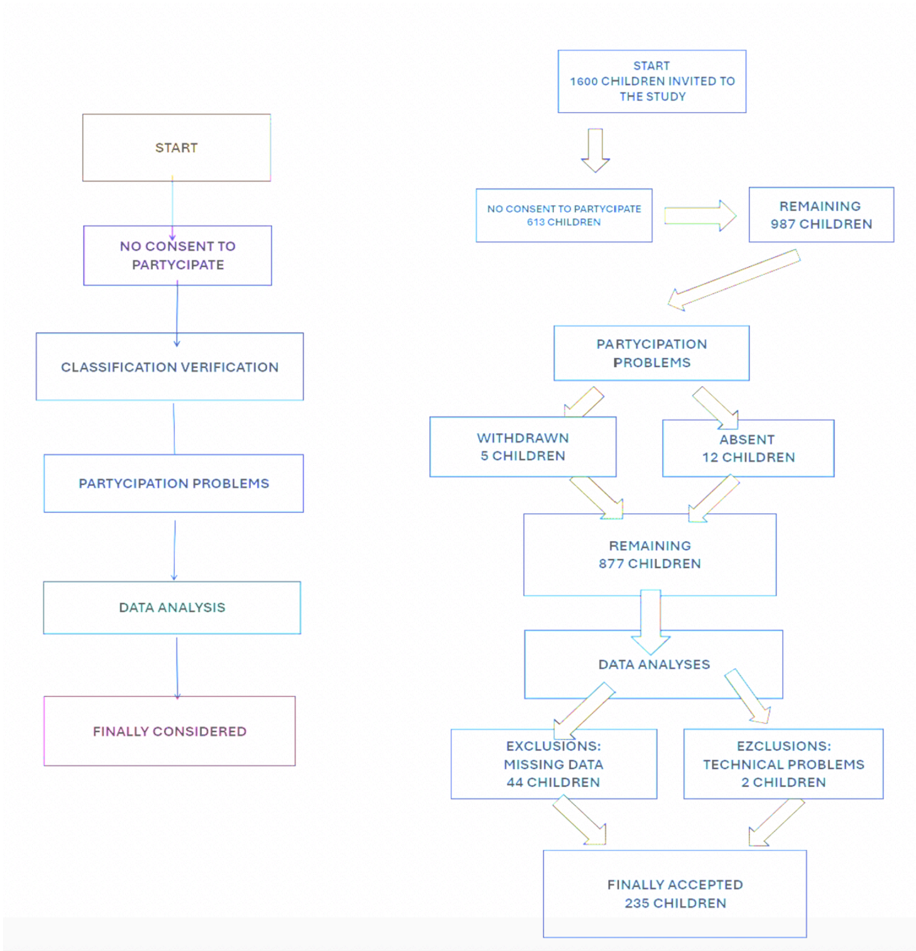
(b) Give reasons for non-participation at each stage

The Flowchart is above © illustrating the stages of participant recruitment, including the number of people at each stage of recruitment and reasons for non-participation:

- **1,600 children invited** to the study.
- Of these, **613 children** did not consent to participate.
- **93 children** were excluded because they did not meet the eligibility criteria.
- **294 children** were found eligible for the study.
- During the study, **5 children** withdrew from participation and **12 children** did not participate due to absence.
- Ultimately, **235 children** were included in the analysis.
- **44 children** were excluded due to missing data and **2 children** due to technical data problems.

(a) Consider use of a **flow diagram: below**

(b)



Descriptive data	14*	a)Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **Characteristics of study participants:** **1. Demographic characteristics of participants:** • **Age:**

    - The study participants were children aged **7–9 years** . The mean age of the children was **7.9 ± 0.74** years.
- **Sex:** 120-122
    - The study included **boys and girls** , but detailed data on gender were not precisely provided in the available materials.

2. Clinical characteristics of participants:

- **Body Mass Index (BMI):**
  Participants were divided into groups based on BMI values:
    - **Underweight**: Children whose BMI z- score < -1.0 SD.
    - **Normal weight**: Children whose BMI z- score is between -1.0 SD and +1.0 SD.
    - **Overweight**: Children with a BMI z- score > +1.0 SD.
    - **Obesity** : Children with a BMI z- score > +2.0 SD.

  Ultimately, 4 BMI groups were taken into account in the analysis: **underweight**, **normal body weight**, **overweight** , **obese** .
- **Health status:**
  Participants had to meet certain health criteria:
    - Children without postural defects such as scoliosis or Scheuermann's disease. 124-138
    - Children who did not have problems with the musculoskeletal system (e.g. lower limb injuries).
    - No spinal deformities or other conditions that would prevent participation in the study.

3. Social characteristics of the participants:

- **Location: The study was conducted in primary schools in the Silesian** Voivodeship in Poland. 87-88
- **Types of schools:**
  Participants came from a variety of primary schools, ensuring a representative sample of the child population in the region.

Exposure and potential confounding factors:

- **Exposure (Backpack Load):**
    - Backpack weight was measured as a percentage of the child's body weight. Backpacks were evaluated in two categories:
        - **Normal backpacks** : Load within **10–15% of body weight** .
        - **Overloaded backpacks** : Load exceeding **15% of body weight** . 145-150

  Backpack load factors were analyzed in the context of their impact on children's postural stability, both in the case of "normal" and overloaded backpacks.
- **Confounding factors:**
    - **Gender:** Gender could influence the results and was therefore taken into account in the statistical analysis.
    - **Age:** The age of the children in the study was relatively homogeneous (7-9 years) to eliminate variability due to differences in children's development.
    - **Physical activity:** Although physical activity level was not directly measured, differences in activity level may have influenced stabilometric results . The influence of physical activity was controlled by analysis of confounding variables. 425-440
    - **Lifestyle and diet:** Variables such as children's lifestyle and diet may have influenced body weight and postural stability, but these factors were not directly assessed in this study.
- **Other potential confounding factors:** School Attendance Details: Children's school attendance and schedule variability may have influenced backpack weight on different study days. Backpack weight variability was controlled by recording backpack weight at the beginning of the study day.

		b)Indicate number of participants with missing data for each variable of interest In the study, missing data were analyzed and supplemented according to the specified imputation method. For each variable of interest, missing data were only for some participants. Here are the details of missing data for key variables: **1. Body weight and height (BMI):** ● Missing data: o All weight and height data were measured for each participant, so there were no missing data in this category and these variables were complete for all **235 participants**. **2. Backpack** weight: ● Missing **data:** o Backpack weight data were collected from all participants, but **2 children** had missing data in this category. These were children who did not have complete measurements or did not bring their backpack on the day of the study. These children were excluded in the final stage of recruitment. **3. Stabilometric parameters (SPL, WoE, HoE, AoE, BWD):** ● Missing data: o **44 children** were excluded from the final analysis of stabilometric data due to missing measurement results. This was due to technical problems or measurement errors during stabilometric testing. To sum up: ● **Body weight, height, BMI**: No missing data occurred. ● **Backpack weight**: Missing data for **2 children**. ● **Stabilometric parameters**: Missing data for **44 children** due to measurement errors. ● **BMI groups**: Complete data for all **235 children**. ● **Confounding variables (age, gender)**: There were no missing data.	Flow diagram above & 97-124
Outcome data	15*	Report numbers of outcome events or summary measures ● **235 children** had complete data for analysis, including body weight, height, backpack weight, and stabilometric results . ● For each outcome variable (e.g. SPL, WoE , HoE), mean values were calculated and then analyzed in the context of backpack load and BMI categories. ● **44 children** were excluded from the analysis of stabilometric results due to missing or erroneous data. ● **2 children** had missing data on backpack weight, but stabilometric data were available.	97-124
Main results	16	a)Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included **Schoolbags' parameters** The weight of schoolbags among younger grade children ranges from 1.5 to 8.0 kg (3.74 ±1.31). Typically, this constitutes 13.66% of their body weight (SD, 5.85), but in 77 cases among the total participants (32.77%), the schoolbags are overloaded by an average of 5.5% (SD, 4.66). However, it should be noted that in the group of underweight children, this overload exceeding recommendations affects as many as 63% of the respondents, compared to only 10% among overweight children and 0.09% among obese children. For children with normal body weight, this value exceeded one-third	188-194

Table II. Schoolbags' parameters in the groups taking age division into account.

Table II in manuscript

Schoolbags' Parameters	Ia (n=49) X ± SD (Range)	Ib (n=48) X ± SD (Range)	Ic (n=33) X ± SD (Range)	II (n=105) X ± SD (Range)	K-W Test H (df); p
Weight (kg)	3.78 ± 1.39 (1.6 – 7.6)	3.64 ± 1.09 (1.60 – 5.50)	3.92 ± 1.28 (1.50 – 6.60)	3.74 ±1.38 (1.6 – 8.0)	1.22 (3); 0.773
% SW vs. BW	17.14 ± 7.02 (7.14 – 38.19)	11.15 ± 3.45 (5.31 – 19.57)	10.19 ± 3.96 (3.52 – 20.96)	14.27 ± 5.61 (6.20 – 28.57)	35.31 (3); <0.0001 [bdef]
% ↑ GIS norm	5.94 ± 6.02 (0.17 – 23.19)	2.27 ± 1.94 (0.11 – 4.57)	3.82 ± 2.53 (1.02 – 5.96)	5.51 ± 3.57 (0.19 – 13.57)	3.99 (3); =0.262

Abbreviations: Ia – group with underweight; Ib – group with overweight; Ic – group with obesity; II – group with healthly weight; %SW vs. BW – % schoolbags weight vs. body weight; % ↑ GIS norm- % above the GIS norm; X – average; SD – standard deviation; K-W: Kruskal-Wallis test. Notes: Notes: [a] difference between Ia and Ic; [b] difference between Ib and Ic; [c] difference between Ia and II; [d] difference between Ia and Ib; [e] difference between Ib and II; [f] difference between Ic and II.

Stabilometric parameters (SPL, WoE , HoE , AoE , BWD):
Some of the main results of the stabilometric parameters are as follows:

- **SPL (Sway Path Length)** :

Obese children had a mean SPL of **224.76 mm** , overweight children 24**4.26 mm** , normal weight children **254.19 mm** , and underweight children **228.06 cm** .

- **WoE (Width of the Ellipse)** :

Obese children had a mean WoE of 7.74 mm , overweight children 9.09 mm , normal weight children 8.66 mm , and underweight children 7.23 mm .

Table III in manuscript

- **HoE (Height of the Ellipse)** :

Obese children had a mean HoE of 7.74 cm , overweight children 9.09 cm , normal weight children 8.66 mm , and underweight children 7.23 mm .

- **AoE (Area of the Ellipse)** :

Obese children had a mean AoE of 211.91 mm² , overweight children 345.79 mm² , normal weight children 289.87 mm² , and underweight children 181.17 mm² .

- **BWD (Body Weight Distribution)** :

Obese children had a mean BWD of 7.87 (indicating greater asymmetry in body weight distribution), overweight children 8.10 , normal weight children 7.98 , and underweight children 8.28.
The difference in weight distribution between the right and left side (ΔBWD) in tests with and without a backpack during the Eyes-Open and Eyes-Closed trials is shown in Figure 1. No significant difference between the groups in individual trials was observed (p=0.317). An increase in the asymmetry difference between sides was noted in the trial without a backpack during the Eyes-Closed test compared to the Eyes-Open test in groups Ia, Ib, and II, as well as a decrease in ΔBWD in group Ic, but these were not statistically significant

(p=0.46, p=0.247, p=0.55, and p=0.16, respectively). In the test with a backpack, results in both trials were comparable (all p>0.23). In the underweight and overweight groups, a phenomenon of asymmetry equalization in foot loading was noted (X^2Ia=8.26, df=3, p=0.04 and X^2Ib=16.06, df=3, p<0.001, respectively), though it significantly worsened other stabilometric parameters

Table III Comparison of the results of posturographic tests conducted during free-standing position without a schoolbag between the groups (Ia,Ib,Ic,II) in trials: Eyes Open and Eyes Closed.

Posturographic Parameters	**Eyes - Open**				**Eyes - Closed**				p_1	p_2
	Ia	**Ib**	**Ic**	**II**	**Ia**	**Ib**	**Ic**	**II**		
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)		
ΔBWD	8.28 (6.44)	8.10 (6.79)	7.87 (6.78)	7.98 (8.86)	8.86 (4.47)	8.43 (6.28)	6.94 (6.27)	8.07 (6.57)	0.993	0.556
MCoCx	8.21 (7.23)	10.18 (8.14)	16.25 (34.44)	10.31 (10.11)	10.09 (8.49)	11.25 (10.31)	10.11 (8.27)	10.89 (9.88)	0.131	0.911
MCoCy	14.12 (8.51)	13.24 (9.53)	16.10 (15.03)	15.92 (12.14)	14.52(10.73)	12.98 (11.93)	15.52 (16.42)	14.47 (11.29)	0.496	0.818
SPL (mm)	228.06 (189.17)	244.26 (119.99)	224.76 (87.36)	254.19 (129.07)	292.14(134.87)	317.84 (123.83)	298.45(132.21)	309.53(146.38)	0.451	0.718
WoE (mm)	7.23 (3.19)	9.09 (6.03)	7.74 (4.13)	8.66 (5.37)	8.84 (7.64)	9.71 (5.28)	6.84 (3.85)	9.42 (6.72)	0.227	0.179
HoE (mm)	11.65 (5.05)	14.23 (10.40)	13.74 (7.76)	14.01 (8.34)	13.85 (6.52)	17.07 (9.05)	14.34 (6.95)	15.88 (10.26)	0.361	0.276
AoE (mm^2)	181.17 (118.85)	345.79 (589.44)	211.91 (168.95)	289.87 (357.69)	284.74(310.22)	381.41 (344.38)	235.88(241.38)	360.33(651.51)	0.117	0.474
aoE (°)	15.00 (17.00)	23.21 (22.37)	16.06 (16.81)	23.95 (22.72)	14.93 (17.01)	17.91 (19.41)	13.34 (14.04)	16.69 (16.58)	0.039^{ab}	0.621

(*b*) Report category boundaries when continuous variables were categorized – not applicable

(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – not applicable

Other analyses 17 Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses

The predictors and their correlations with posturometric parameters

In the following section, predictors that may influence stabilometric outcomes were identified, namely: BMI (percentiles), school back-pack weight (SW), and the percentage of school backpack weight relative to the subject's body weight (%SW). Stepwise regression analysis was used to identify potential predictors for specific variables in the posturographic tests presented in the table below (Table 6) for tests with a backpack under both open-eye and closed-eye conditions. Table 6 summarizes descriptive statistics and the results of parameter analysis for posturographic measurements with eyes open and closed. As indicated by the regression results, in the tests with eyes open, only the variables McoCy and HoE correlate with the school backpack weight. In tests with a backpack under closed-eye conditions, only WoE shows a correlation. Subsequently, it was examined whether the backpack weight and the proportion of backpack weight relative to body weight are related to posturographic parameters. It turned out that this relationship is present only in part and primarily in the underweight group and the group with normal body weight. In the open-eye tests, in the underweight group, there is a linear relationship between school backpack weight and SPL, WoE, HoE, AoE, and aoE, as well as for the percentage of backpack weight relative to body weight in both tests. In the group of children with normal body weight, closing the eyes amplifies the correlation of the aforementioned parameters with the school backpack weight, but this relationship is not observed when analyzing the percentage load. 249-267

Discussion

Key results	18	Summarise key results with reference to study objectives	274-277

To summarize the key findings of the study, it can be stated that the main objectives of the study were met, and the results showed significant relationships between backpack load, body mass (BMI) and postural stability of children. Here is a detailed discussion of the key findings in the context of the study objectives:

1. The influence of backpack load on postural stability:

Study objective:

To assess the effect of backpack load (in percentage of body weight) on postural stability of children with different body weight categories (underweight, normal weight, overweight, obese). 207-270

Key result:

- Children with **overloaded backpacks** (over 15% of body weight) had **significantly worse postural stability scores** compared to children with backpacks within the norm (10–15% of body weight).
- Children with overloaded backpacks showed higher values in stabilometric parameters such as **SPL, WoE , HoE , AoE** , which indicates poorer balance and postural stability.

This indicates **a significant impact of backpack load on children's ability to maintain balance**, especially in the case of backpacks exceeding 15% of their body weight.

2. The influence of body mass (BMI) on postural stability:

Study objective:

To analyze the influence of body mass (BMI) on postural stability of children, including the assessment of differences in stabilometric results between groups with different BMI categories (underweight, normal weight, overweight, obese).

Key result:

- Children with **obesity** had **significantly worse results in postural stability** compared to children with normal body mass. Parameters such as **SPL, WoE , HoE** were higher in the group of children with obesity, which indicates greater difficulties in maintaining balance.
- **Overweight** children also performed worse, although the differences compared to the normal weight group were smaller.
- **Underweight children** had **the best postural stability scores,** suggesting that lower body weight may be associated with better postural balance, although these results may also be due to lower musculoskeletal loading.

3. Interaction between backpack load and body mass (BMI):

Study Objective:

To assess the interaction between backpack load and BMI category to determine whether the effect of backpack load differs by body mass category.

Key result:

- **The interaction between BMI and backpack load** was found to be significant. Obese children who wore overloaded backpacks (over 15% of body weight) had **significantly worse postural stability scores** compared to children with normal body weight and backpacks within the norm.
- Children with a higher BMI (especially those with obesity) were more **sensitive to the negative effects of heavy backpack weight,** which may lead to a greater risk of postural problems in the long term.

4. The influence of confounding factors on the results:

Study objective:

To control for confounding variables such as age, gender, and physical activity level in order to obtain reliable results and exclude possible sources of error in the analyses.

Key result:

- After adjusting for confounding variables (age, gender, physical activity level), postural stability results remained consistent and confirmed that **children with obesity** and **children with overloaded backpacks** had **poorer postural stability scores.**
- Sensitivity analysis showed that **the method of imputing missing data** did not significantly affect the results of the analysis, suggesting that the results were stable and reliable.

Summary:

- **Backpack load** and **BMI category** have a significant impact on **children's postural stability.** Children with overloaded backpacks and children with obesity show **poorer postural stability.**
- **The interaction between backpack load and BMI** shows that children with obesity are more likely to experience the negative effects of backpack load, which may lead to long-term postural health problems. 452-455
- **Confounding factors** such as age, gender and physical activity level were adjusted for and did not significantly affect the main results, which confirms the reliability and validity of the study results

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Limitations 19 Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias

Our research provides hard evidence supporting the necessity of decision-making regarding the weight of school backpacks and systemic solutions. We designed and conducted the study to meet PEDro scale items (Brzęk et al. 2024), ensuring it was as reliable and valid as possible. However, this study has certain limitations that should be considered.

First, although the sample is representative of the school population, the results cannot yet be generalized to the national level but only to the regional scale, as the research was conducted in various schools and cities in the Silesian region. While the sample size may appear small, it was deemed sufficient based on power analysis. It is important to note that among children with overweight and obesity, it is challenging to meet the criterion of an absence of postural abnormalities, which was crucial to this study. Any postural defects or spinal deformities activate compensatory and adaptive mechanisms that influence posturographic parameters. 422-433

In this study, the authors prioritized conducting research while excluding factors that could disrupt postural stability. One could argue that a certain limitation is the lack of research conducted in dynamic conditions; however, this was the premise of this project—to carry out the study in static conditions. It would be worth considering continuing this research in dynamic conditions as well, but in the authors' opinion, it should be conducted in a school environment rather than in laboratory conditions.

Sample size and representativeness:

- **Limit:**
  - Although the study included 235 children, the sample came from a single location (Silesian Voivodeship), which may limit **the representativeness of** the results for the entire population of children in Poland. Therefore, the results may not be fully generalizable to other regions of the country, as well as to other demographic groups (e.g. children from different socioeconomic groups).
- **Potential error:**
  - **The bias associated with a geographically limited sample** may lead to underestimation or overestimation of results depending on the specific characteristics of the study population (e.g. children in large cities may have different patterns of physical activity and backpack load than children in rural areas).

Backpack load error:

- **Limit:**
  - **Backpack weight** was measured at the beginning of the day, which may not reflect the full load during the school day when children may have different loads depending on the number of books and materials.

- **Potential error:**
    - **The error associated with measuring the weight of a backpack on a single occasion** can distort the results, especially if the weight of the backpack changes throughout the day.
- **Error scale:**
    - The potential error associated with measuring backpack weight can be **5-10%** , especially when the backpack is subject to variability in load.
    -

Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence Although this study provides valuable information on the effects of backpack weight and BMI on children's postural stability, caution should be exercised in interpreting the results. Limitations related to sample representativeness, incomplete control for confounding variables (e.g., physical activity), missing data, and omission of other factors (e.g., diet, sleep) may affect the accuracy of the results. Therefore, although the results indicate significant associations, these limitations should be taken into account when drawing conclusions and making recommendations. The results indicating that the weight of the backpack and the percentage of this weight relative to the child's body mass do not serve as predictors influencing stabilographic parameters seem very intriguing. However, additional loading on the child's back worsens their performance in this area. In underweight children, there are correlations between the backpack's weight, the percentage of this weight relative to the child's body mass, and stabilographic parameters—relationships that were not observed in groups with increased body mass. In these groups, there was a statistically significant deterioration in results when the child's back was loaded with additional weight. This allows the authors to explore further causes of this phenomenon but also to conclude that, particularly in this group, any additional weight placed on the child's back will affect postural stability. Therefore, it is worth considering these findings and conducting more in-depth research in the group with obesity-related conditions. In other independent studies conducted over many years, observing the same children over time, a significant systemic problem has been identified (Brzęk & Plinta 2016). Training sessions and workshops carried out as part of projects funded by the Polish Ministry clearly highlight an issue raised by parents: children's class schedules do not allow for lighter packing of backpacks, despite parents' considerable efforts and monitoring of backpack weights. This problem requires a systemic solution (Brzęk et al. 2017; Wysocka et al. 2024). Such a solution will soon be presented in upcoming publications, which are currently at a very advanced stage, focusing on the design of an innovative school backpack, and the results are already promising.	401-421

Generalisability	21	Discuss the generalisability (external validity) of the study results **Representativeness of the Sample:** ● **Geographical and Demographic Representativeness:** • The research sample was drawn from Poland, and the results can be generalized to other regions, especially those with similar socio-economic, urbanization, or cultural conditions. • Furthermore, the study included children aged 7–9 years, making the findings applicable to this age group. • An additional advantage is the division into categories based on BMI percentiles, which demonstrates the possibility of application in a population of children with varying body weights. • The use of polished devices facilitates the repeatability of measurements. • The possibility of conducting research in this area based on our resources is extensive and allows for comparisons between countries. The lack of such research reinforces this need.	432-440
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based No external funding. The research was funded as part of statutory research of the Medical University of Silesia in Katowice under the number: PNW-1-091/N/3/Z.	457-458

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.