ISSN 0008-3194 (p)/ISSN 1715-6181 (e)/2024/131–141/$2.00/©JCCA 2024

Musculoskeletal symptomatology in skeletally immature students carrying heavy backpacks: a cross-sectional study

Zehra Alvi[1]
Ali Alvi[1]
Melanie A. Mascarenhas, MA[2,3]
Mansour Alvi, PhD, MD[4]
Konstantine K. Zakzanis, PhD[1,3]

Background: *Young students with skeletal immaturity report an increasing number of musculoskeletal symptoms associated with daily use of heavy backpacks. This cross-sectional study investigated the relationship between heavy backpack use and reports of pain.*

Methods: *Data were collected from 300 students aged 11 to 18 at the University of Toronto Schools.*

Results: *Students, on average, carried 15.9% of their body weight. 54% of students reported physiological complaints, primarily back, shoulder, neck, and leg pain. Backpack weight as a % of body weight was strongly associated with pain complaints. Younger students and those with longer commutes were more likely to report heavy backpacks (50% compared to 22.6% of older students, p< .001) and pain.*

La symptomatologie musculosquelettique chez des étudiants dont le squelette est immature, et qui portent des sacs à dos lourds : une étude transversale

Contexte: *Les jeunes étudiants souffrant d'immaturité squelettique signalent un nombre croissant de troubles musculosquelettiques des symptômes associés à l'utilisation quotidienne de sacs à dos lourds. Cette étude transversale a examiné la relation entre l'utilisation de sacs à dos lourds et les signalements de douleurs.*

Méthodes: *Les données ont été recueillies auprès de 300 étudiants âgés de 11 à 18 ans dans les écoles de l'Université de Toronto.*

Résultats: *Les étudiants, en moyenne, portaient 15,9 % de leur poids corporel. 54 % des élèves ont signalé des troubles physiologiques, principalement des douleurs au dos, aux épaules, au cou et aux jambes. Le poids du sac à dos exprimé en pourcentage du poids corporel était fortement associé aux douleurs. Les étudiants plus jeunes et ceux qui ont des trajets plus longs étaient plus susceptibles de déclarer avoir des sacs à dos lourds (50 % comparativement à 22,6 % des étudiants plus âgés, p< .001), ainsi que des douleurs.*

[1] University of Toronto St. George, Department of Human Biology
[2] University of Toronto Scarborough, Department of Psychological Clinical Science
[3] University of Toronto Scarborough, Department of Psychology
[4] Scarborough Health Network, Toronto, ON

Corresponding author: Konstantine K. Zakzanis, University of Toronto, Scarborough, 1265 Military Trail, Toronto, Ontario, M1C 1A4
Tel: (416) 287 7424.
Fax: (416) 287 7642
E-mail: konstantine.zakzanis@utoronto.ca

The authors have no disclaimers, competing interests, or sources of support or funding to report in the preparation of this manuscript.

Conclusion: *Carrying heavy backpacks could result in increased musculoskeletal complaints in young students. Findings suggest that even the upper bound of currently recommended guidelines (20% of body weight) may be too high, especially for younger children.*

(JCCA. 2024;68(2):131-141)

KEY WORDS: back pain, students, pain, child health, cross-sectional studies

Conclusion: *Le port de sacs à dos lourds pourrait entraîner une augmentation des plaintes musculosquelettiques chez les jeunes élèves. Les résultats suggèrent que même la limite supérieure des recommandations actuelles (20 % du poids corporel) pourrait être trop élevée, en particulier pour les jeunes enfants.*

(JCCA. 2024; 68(2) : 131-141)

MOTS CLÉS : douleur dorsale, étudiants, douleur, santé de l'enfant, études transversales

Introduction

According to recommendations from the American Academy of Pediatrics (AAP), a child's backpack should not exceed 10 to 20 percent of their body weight, with a new study stating that any backpack exceeding 15% of the carrier's bodyweight can result in musculoskeletal complaints.[1,2] Consequent research has further suggested the limit should be lowered and not exceed 5-10% of body weight.[3-5] There remains a lack of clarity on this topic, as there is currently no universal guideline for backpack weight, varying recommendations on weight, and little evidence that it has been shared with students and parents.[6] Despite this, research has demonstrated that a heavy backpack is a notable contributor to lower-back pain in children and that carrying a heavy backpack for long periods, carrying it on one shoulder instead of two, and climbing stairs while lugging a heavy load can exacerbate the problem.[7-11] This issue warrants further investigation as the detrimental health effects can be combatted by increasing awareness of ergonomic principles, including a backpack's content and weight.[6,7,12]

The effects of carrying heavy backpacks have come under global investigation, as evidenced by research conducted across Europe.[4,13-19] Studies have observed an increase in thoracic kyphosis as students have to adjust their centre of gravity to bear the weight, particularly when the weight carried surpasses 10% of body weight.[20] Although neck pain and lower back pain are experienced by individuals of all ages, these problems become an increasing concern in adolescence, with the prevalence rates ranging from 21% to 42%.[12,21] Consequently, this can warrant increases in consultations with health professionals and medication prescription, which can burden the healthcare system while simultaneously leading to reduced physical activity in children and higher rates of pain-related school absences.[21] Thus, determining an acceptable limit for a child's backpack and ensuring it is shared with stakeholders is essential in reducing back, neck, and shoulder injuries and preventing poor posture.[6,22] The combined effects of a heavy load, position on the body, size and shape, distribution, and time spent carrying the load, further influenced by the physical characteristics and condition of the individual, are considered factors that may be associated with these problems.[8]

While efforts have been made to set a weight limit for students' backpacks, not enough is done to share and enforce such limits.[6] Early adolescence (during middle and high school years) is a critical developmental period for spinal growth.[23] During this time, the early and mid-adolescent spine increases in length and volume without substantially adding mass, thereby causing the adolescent spine to be less able to withstand stresses that are considered normal for the adult spine.[24-27] Furthermore, experiencing lower back pain as a child or adolescent is strongly associated with chronic lower back pain in adulthood.[28] Preventive measures and appropriate guidelines regarding safe backpack weights for school children are essential in the reduction of musculoskeletal complaints among children to prevent the chronicity of such issues in adulthood.

Accordingly, we first sought to determine if the average backpack weight that students (aged 11-18) were carrying exceeded the recommended guidelines outlined by the AAP. Here, we additionally wanted to determine

if carrying overweight backpacks was associated with musculoskeletal (pain) complaints among these skeletally immature students. We investigated the relationship between musculoskeletal complaints and the average weight being carried and, in turn, determined whether carrying overweight backpacks was related to compromised health. To this end, we examined the subjective perception of pain and daily backpack load to ascertain whether an association exists. We also explored factors such as the time spent carrying a backpack to school and other variables that could further affect the subjective backpack load and related musculoskeletal complaints.

Methods

Ethics approval was obtained prior to the commencement of the study through the institutional Research Ethics Board Review Committee. Informed student consent and parental consent were both obtained. Students and staff were briefed regarding the purpose of the study. The study was designed and conducted by members of an academic club at the University of Toronto Schools (UTS), a merit-based middle and high school in the Greater Toronto Area. Two members were responsible for data collection. Additionally, a faculty member supervised the study progression. All procedures were in accordance with Canada's Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans.

Participants

Participants were recruited at the UTS Institute in the city of Toronto, Ontario, over a period of six months. An email detailing the study was sent to all students, allowing them to opt in or out of the study, with no incentive offered to participants. Of 612 eligible participants, 11 students opted out of participation. Of the remaining 601 interested students, stratified random sampling was used to recruit equal numbers of males and females for a total of 50 students from each grade (grades 7 through 12). Younger students were categorized as Grades 7 – 9 (ages 11 – 14) and older students as Grades 10 – 12 (ages 15 – 18). Figure 1 illustrates the participant eligibility and selection process.

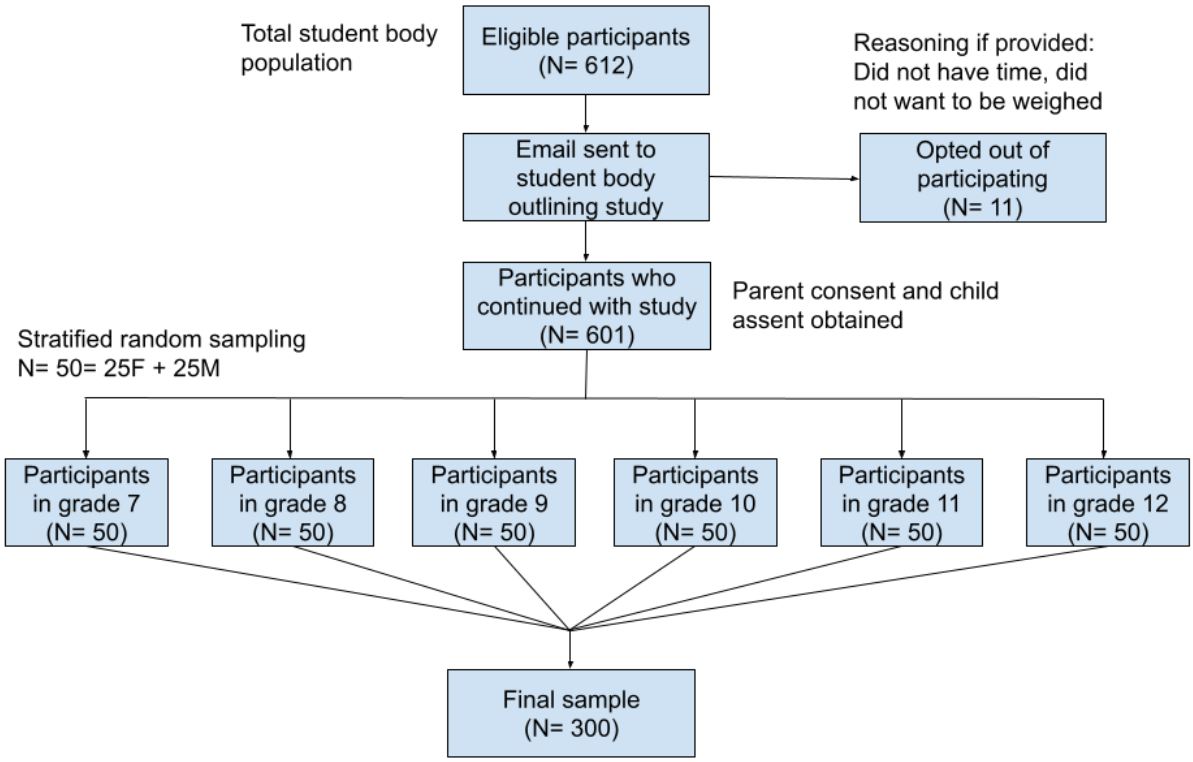

Figure 1. *Flowchart of Participant Eligibility and Selection*

Sample size justification

The sample was determined based on consideration of research objectives and representation of the target population. This investigation explored musculoskeletal concerns associated with carrying overweight backpacks among grades 7-12 students. For a comprehensive and unbiased sample, stratified random sampling was used.

A power analysis determined that the minimum required sample size for this study was 210 participants (effect size of 0.25, $\alpha = 0.05$, power $[1-\beta] = 0.95$). Previous research in this field have highlighted the absence of a standard reference effect size. This has made determining the appropriate sample size challenging due to a lack of literature. For example, one study recruited 123 students based on an estimation that pain prevalence was 30% with a confidence level of 95%.[10]

The student body comprised of 612 students, with 102 in each grade level. For equitable representation, 50 students (25 female and 25 male) were randomly selected from each grade, yielding a total sample size of 300 students, equally distributed across genders. Thus, data were collected from 50% of the student body, ensuring inclusivity of diverse student backgrounds and facilitating generalizability to the broader school context. This was done to mitigate potential bias from over or under-representation of grades or genders. The chosen sample size ensured the statistical power for detecting anticipated effects and enhanced the validity of the findings by adhering to ethical principles for addressing the research objectives.

Data collection

Data collection was conducted consecutively, beginning with the recruitment of students in Grade 7 and ending with students in Grade 12. Data collection took place on random days such that students would not be influenced by the study and alter their backpack's weight in anticipation of the data collection. All data were collected in the morning following each student's arrival, at lunch, and before departure from school. First, a consent form and a questionnaire to gather primary data were administered. The questionnaire included details about age, gender, grade, body weight, height, area of residence, commute type, duration of commute, backpack weight, subjective perception of backpack weight, items in the backpack, how it is carried, physical complaints, frequency of physical complaints, medical intervention, any medical diagnosis, and any use of medications. The study ensured that all students used a dual-strap backpack, with all participants reporting they carried the load on both shoulders. Regarding physical complaints, students were asked if they experienced any musculoskeletal complaints, such as pain in the neck, shoulder, lower back, or leg(s). Second, the weight of the backpacks was obtained using a Klau Hanging Scale with the capacity to measure between 0.2 kg and 500 kg with high precision. The validity of this instrument was tested using functional cuff weights of 0.45 kg, 1.36 kg, and 2.27 kg, revealing accurate measurements over repeated trials. Third, the weight of participants was collected using a Seca 803 digital floor scale, calibrated at the start of each day of data collection. Finally, the height of participants was measured using a Health O Meter professional wall-mounted height rod.

Analyses

The Statistical Package for the Social Sciences (SPSS, Version 28.0) was used for all data analysis.[29] Backpack weight as a % of bodyweight was measured on a continuous ratio scale. Chi-square tests were conducted to assess objective backpack weight (as a percentage of body weight) and commute time on the pain response in students. Independent samples t-tests and analyses of variance (ANOVA) were conducted to assess differences in outcomes across groups of categorical variables (reported pain complaints, subjectively perceived heaviness of bags). All assumptions were assessed and met for each analysis.

Results

Sample characteristics and outcomes are summarized in Table 1. The present study found that 75% of students carried a backpack that was more than 10% of their body weight, and 17% of students carried a backpack more than 20% of their body weight. On average, students carried 15.9% of their body weight, and approximately 54% reported physiological impacts with primarily back, shoulder, neck, and leg pain complaints. On average, younger students (Grades 7 – 9; ages 11 – 14) were carrying heavier backpacks in proportion to their body weight compared to older students (Grades 10 – 12; ages 15 – 18) (Table 1). The average backpack weight to bodyweight ratio for younger students was 17.7%, compared to 13.6% for older students. In addition, younger students

were more likely to be carrying backpacks that were more than 10% (98%, 92%, and 94% of students in grades 7, 8, and 9, respectively), or 20% (44%, 36%, and 20% of students in grades 7, 8, and 9, respectively) of their body weight. There was no great difference in the average backpack weight alone, with younger students carrying backpacks weighing 8.3 kg and older students carrying backpacks weighing 7.9 kg. However, the average body weight of younger students was 47.24 kg while, in comparison, the average body weight of older students was 58.35 kg. Here, the younger group's lower body weight had a significant impact on the backpack-to-bodyweight ratio.

Students in younger grades 7 – 9 were more likely to report their backpacks as being heavy compared to older students in grades 10 – 12 [50% compared to 22.6%, χ^2 (5, n = 300) = 75.54, p < .001]. In addition, a higher proportion of students in grades 7 – 10 reported musculoskeletal pain complaints (66%, 56%, 62%, and 72%, respectively) compared to students in grades 11 and 12 (34% and 32%, respectively), a statistically significant difference in proportions, χ^2 (5, n = 300) = 28.54, p < .001. Figure 2 and Figure 3 further illustrate these differences.

The relationship between objective backpack weight, subjective perception of backpack weight, and pain

An independent samples t-test revealed a significant difference in the relative backpack weight as a % of body weight between students who reported pain complaints (M = 17.2, SD = 4.2), and students who reported no pain (M = 14.3, SD = 3.8), t(298) = -6.1, p < .001).

To assess the relevance of AAP guidelines with regard to reports of pain, a chi-square test found that 21.1% of students were carrying less than 10% of their body weight reported physical pain complaints, compared to 50.6% of students carrying between 10-20% of their body weight and 80% of students carrying more than 20% of their body weight, a statistically significant difference in proportions, χ^2 (2, n = 300) = 22.92, p <.001 (Figure 4).

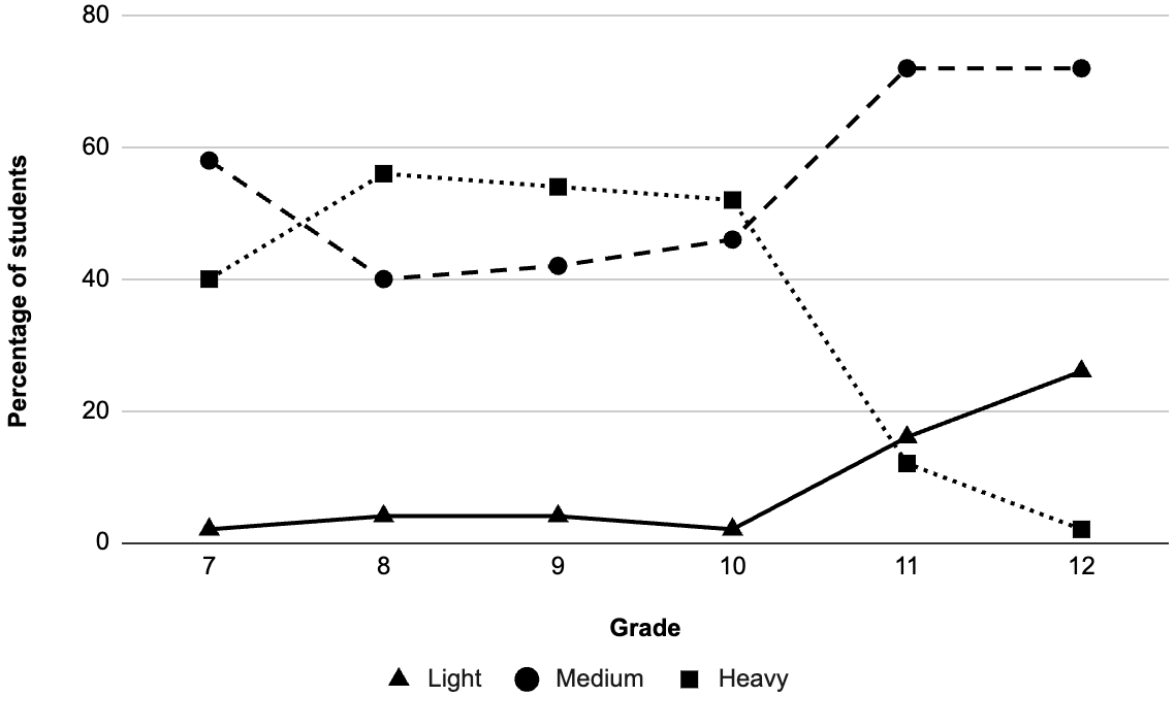

Figure 2.

Reports of subjective perceptions of backpack weight by grade (Note. A greater percentage of younger students (Grades 7-10) reported heavy backpacks compared to older students (Grades 11-12). Similarly, a greater percentage of older students reported light backpacks compared to younger students). (—▲—) reports of light backpacks; (— ● —); reports of moderately heavy backpacks; (•• ■ ••) reports of heavy backpacks.

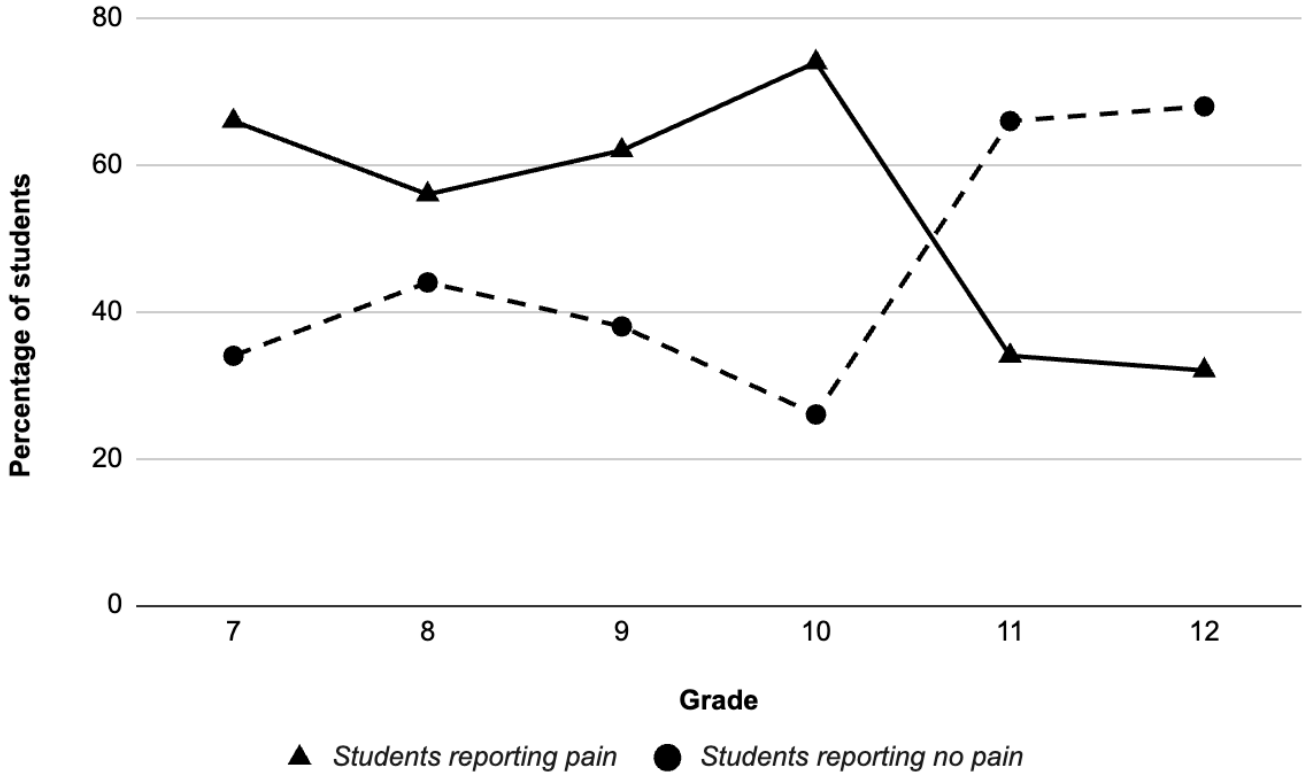

Figure 3.
Reports of pain by grade (Note. A greater percentage of younger students (Grades 7-10) reported musculoskeletal pain compared to older students (Grades 11-12)). (—▲—) reports of pain; (— ● —), reports of no pain.

To determine whether students' subjective reports of their backpack weight were related to the objective weight of their backpacks, a one-way ANOVA revealed significant differences in the backpack weight as a % of body weight between students who reported their bags as very heavy (M = 18.34, SD = 3.86), moderately heavy (M = 15.01, SD = 3.63) and light (M = 11.08, SD = 2.81), $F(2, 297) = 52.67$, $p < .001$, $\eta 2 = .26$, indicating a large effect size (Cohen, 1988). Further, a chi square test revealed significant differences in the proportion of students who reported pain complaints between those who reported their backpacks as very heavy (76.1%), moderately heavy (43.3%), and light (25.9%), χ^2 (2, n = 300) = 37.61, p <.001.

The relationship between commute time, subjective perception of backpack weight, and pain

A chi-square test found that 83% of students with a commute time of greater than two hours reported physical pain, compared to 51% of students with a commute time of between one and two hours, 57% of students with a commute time of between 30 minutes and one hour, and only 39% of students with a commute time of fewer than 30 minutes, a statistically significant difference in proportions, χ^2 (3, n = 300) = 11.44, p =.01 (Figure 5). Specifically, a commute time of over two hours resulted in significantly more reports of physical pain than shorter commute times (i.e., less than 30 minutes).

Further, students were more likely to report their bags as being very or moderately heavy (as opposed to being light) if they had a longer commute. Here, 100% of students with a commute time of greater than two hours reported heavy backpacks, compared to 96.4% of students with a commute time of between one and two hours, 88.2% of students with a commute time of between 30 minutes and one hour, and 62.5% of students with a commute time of fewer than 30 minutes, a statistically signifi-

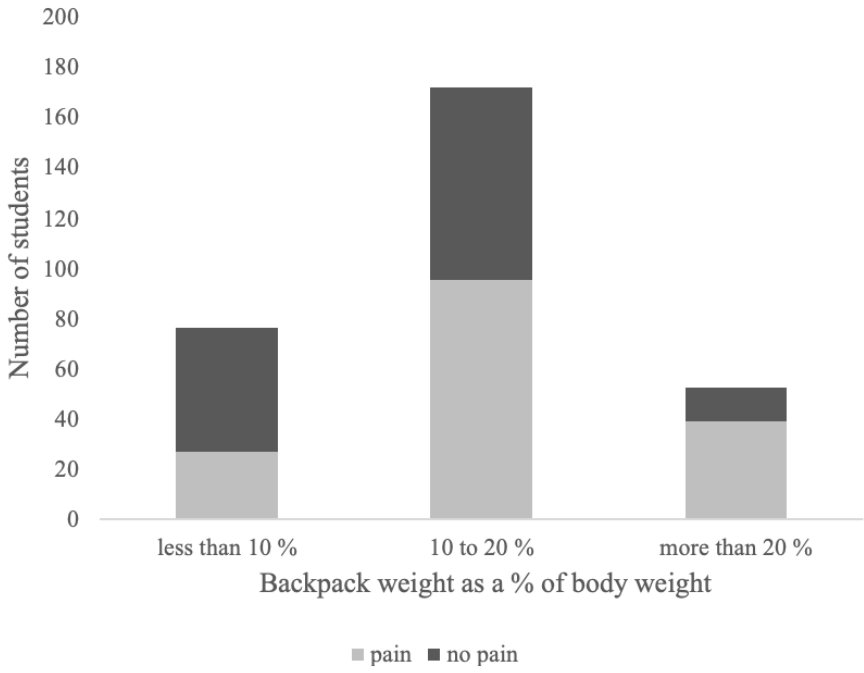

Figure 4.

The relationship between backpack weight and pain complaints (Note. On average, students carrying a heavier percentage of their body weight reported significantly more pain complaints. (▒), pain; (■), no pain).

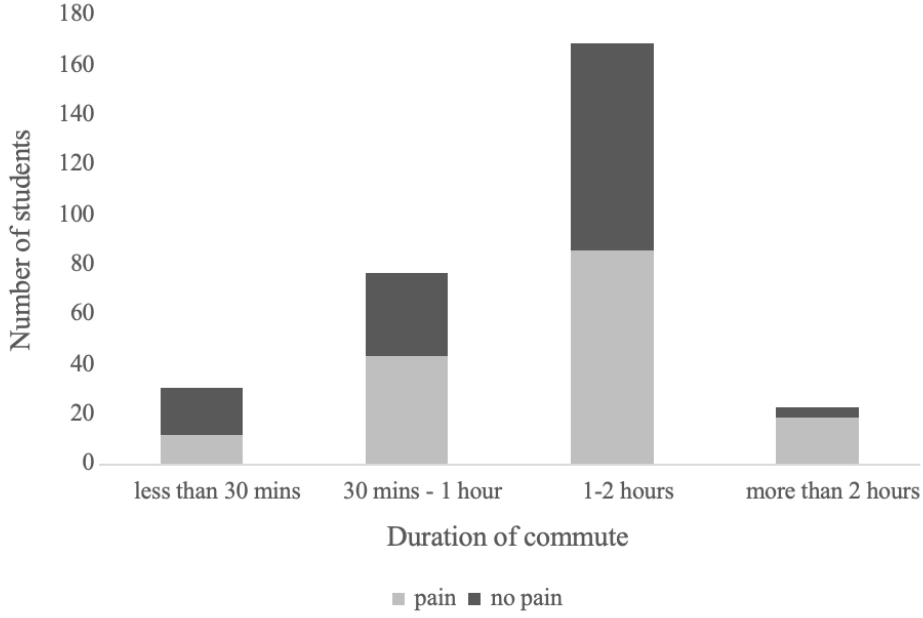

Figure 5.

The relationship between duration of commute and pain complaints (Note. Duration of commute was related to pain complaints; there were significantly more reports of pain among students with commute times of over two hours compared to those with shorter commute times). (▒), pain; (■), no pain.

cant difference in proportions, χ^2 (3, n = 300) = 42.70, p <.001. No significant differences were observed for variables such as commute type and area of residence.

The role of additional demographic variables in assessing perceptions of bag weight and pain

Further group-level analyses were conducted to assess the role of demographic characteristics in perceptions of backpack weight and reports of pain. A point biserial correlation revealed a small but significant association between height and pain complaints, where pain was more frequently reported among shorter students than taller students (rpb (298) = - .150[-.259, -.037], p = .009). There was no observed effect of sex; reports of pain did not significantly differ between male and female students (50% compared to 57.3%, χ^2 (1, n = 300) = 1.62, p = .203).

Discussion

The AAP recommends that a child's backpack be no more than 10-20% of their body weight.[1] The present study found 75% of all students carrying a backpack more than 10% of their body weight, and 17% of students carried a backpack more than 20% of their body weight. In this sample, 33.3% of younger students ages 11-14 carried backpacks at or over the maximal 20% limit recommended by the AAP. In comparison, 1.3% of older students ages 15-18 surpassed this limit. This appears to be related to the finding that backpack weight remained relatively stable across age groups even though there is a high degree of variance in body weight and height across children aged 11-18. Typically, while backpack weight across ages and grades tended to remain stagnant, lower body weights of younger students appeared to lead to more pain complaints, likely due to the ratio of backpack weight to body weight, which has previously been identified as a predictor of back pain.[7]

Backpack weight as a percentage of the child's body weight was significantly related to the presence of increased pain complaints for all students, as was their subjective perception of this weight. Further, this study and other research found that younger students were much more likely to report musculoskeletal pain as compared to older students.[30] While only 17% of students carried a backpack more than 20% of their bodyweight, the proportion of students with musculoskeletal complaints was much higher, with approximately 54% of students reporting pain primarily in the back, shoulder, neck, and legs. Accordingly, even the upper bound of presently recommended guidelines (20% of body weight) may be too high, especially for younger children.

Prior evidence has suggested that the time spent carrying the backpack, in addition to its weight, is a factor in instances of back pain.[31,32] The present study found that commute duration to school was significantly related to students' perceived backpack weight and their reports of musculoskeletal pain, especially when commute times were longer than one hour. Research has also indicated the impact on musculoskeletal health associated with the distance and time spent carrying the backpack might exceed that of weight alone, thus being a crucial contributing factor considered in this study.[32] With 64% of students reporting a commute greater than or equal to one hour, this poses a significant concern and warrants further consideration.

While previous research on this subject has found a correlation between back pain and the factors identified in this study, they have been unable to identify specific risk factors as a result of inconsistent methods of reporting, as most studies on this topic do not consider the type of back pain, spinal posture and illness factors.[24,30] These reviews call upon future studies to be more rigorous in considering the factors that lead to back pain, which this study addressed by inquiring about the regions of the back affected by back pain and regarding spinal posture and illness factors by inquiring whether participants have been previously diagnosed by medical professionals for any musculoskeletal issues.

The effects of carrying excess weight in school backpacks have been a long-discussed subject in paediatric research, yet students are required to carry loads that exacerbate this problem and cause physical pain.[33] Excessive backpack weight, especially that exceeding 20% of the individual's body weight, has recently gained attention from multiple studies as a major contributor to pain in the early stages of development.[3,34,35] Consequently, back pain in children has become a prominent public health concern.[36]

The backpack was designed to be the appropriate method to load the spine closely and symmetrically while maintaining stability.8 However, risk evaluation when carrying over the recommended maximum weight in a backpack is essential. Exceeding recommended guide-

lines of backpack weight can cause an individual's center of gravity to be displaced which can create excess tension in one's muscles in the back and neck. Such excessive tension is further associated with spinal column dysfunction and a decrease in lung volume.[10] Previous work has also demonstrated an association between backpack weight and musculoskeletal complaints.[33] There is an increased risk to younger children and adolescents considering that their musculoskeletal system is undergoing a period of growth and maturation and considering the frequency of backpack use in this group.[23]

Musculoskeletal problems associated with backpack use are becoming an escalating concern for skeletally immature students.[6] Studies have found that back pain in adolescents is a strong predictor of developing chronic back pain in adulthood.[37-41] Unaddressed back pain can get exacerbated, resulting in long-lasting complications. Prior research has also found that carrying heavy backpacks may lead to detrimental changes in trunk posture and muscle activity.[42]

Limitations

This study has some limitations which must be considered. First, while the sample is representative of the school's population, these results may not be generalizable on a city-wide or regional scale. Further research is required to produce comprehensive data on the pervasiveness of the adverse effects of overweight backpacks among skeletally immature students. Secondly, this study was reliant on self-reported musculoskeletal complaints. As such, data on pain are vulnerable to participant subjectivity and reliability. Finally, the impact of a cross-sectional dataset introduces certain limitations, as the nature of the design restricts the establishment of causal relationships, with data being collected at only one time point. As such, there are limitations in capturing longitudinal changes, potentially overlooking trends and fluctuations in the investigated variables. While this study provides valuable insight into the relationship between backpack weight and musculoskeletal pain, there are limitations in generalizing the findings. Expanded cohort studies with diverse student populations are required to further explore these findings.

Conclusion

In conclusion, the findings of this study demonstrated that the current backpack weight for many (particularly younger) students is higher than recommended guidelines and likely related to a high number of pain complaints. Most students carrying between 10-20% of their body weight reported mild to moderate pain, which is often overlooked in practical settings as it falls below the upper bound of AAP recommended guidelines (i.e., 20% of body weight). Heavy backpacks are an influential factor in the cause of early-age back pain, and previous research has suggested that reducing the load to 10% of body weight can help maintain normal posture.[3,35] The present study's findings could inform further research that aims to address the issue of heavy backpack use. Additionally, considering commute time was significantly related to pain complaints, reductions in the time spent carrying backpacks should be considered. Current recommendations include carrying adequately adjusted backpacks to better fit the child's back, backpacks with padded dual straps, carrying only necessary items, placing the heaviest items closest to the back, the provision of lockers to store heavier items (e.g., textbooks), and division of textbooks into smaller modules.[6,43] These recommendations were provided to UTS to facilitate changes that decrease backpack load for students. Considering that previous research has consistently demonstrated that back pain in adolescence contributes to chronic back pain in adulthood, early intervention in this population is imperative. Ultimately, further research is needed to elucidate the relationship between backpack weight and musculoskeletal pain in early educational settings to create a healthier learning environment for students.

References

1. Grant L. Backpack weight: how heavy is safe? AAP Gd Rounds. 2007; 18(1): 10–11.
2. Djajasasmitan D, Manoe ZJ, Wulandari, F. Relationship between backpack weight and incidence of low back pain in senior high students. Acta Med and Health Sci. 2023; 1(3): 105–111.
3. Moore MJ, White GL, Moore DL. Association of relative backpack weight with reported pain, pain sites, medical utilization, and lost school time in children and adolescents. J Sch Health. 2007; 77(5): 232–239.
4. Al-Hazzaa HM. School backpack. How much load do Saudi school boys carry on their shoulders? Saudi Med J. 2006; 27(10): 1567–1571.
5. Lindstrom-Hazel, D. The backpack problem is evident but the solution is less obvious. Work. 2009; 32(3): 329–338.

6. Dockrell S, Simms C, Blake C. Guidelines on schoolbag use: messaging to inform the stakeholders. Work. 2016; 54(2): 489–492.
7. Siambanes D, Martinez JW, Butler EW, Haider T. Influence of school backpacks on adolescent back pain. J Pediatr Orthop. 2004; 24(2): 211–217.
8. Knapik J, Harman E, Reynolds K. Load carriage using packs: a review of physiological, biomechanical and medical aspects. Appl Ergon. 1996; 27(3): 207–216.
9. Perton M. Aching backs affect children, too. Consumer Reports. https://www.consumerreports.org/cro/news/2009/07/heavy-backpacks-can-add-to-children-s-back-problems/index.htm. July 21, 2009. Accessed August 21, 2022.
10. Hernández TL, Ferré MC, Martí SG, Salvat IS. Relationship between school backpacks and musculoskeletal pain in children 8 to 10 years of age: an observational, cross-sectional and analytical study. Int J Environ Res Public Health. 2020; 17(7): 2487.
11. Dockrell S, Simms C, Blake C. Schoolbag carriage and schoolbag-related musculoskeletal discomfort among primary school children. Appl Ergon. 2015; 51: 281–290.
12. Arrifqi M, Bahrudin, M. Effect of backpack with the incidence of low back pain at 7-20 years of age. APISIO Medika. 2023; 1(1): 29-32.
13. Cardon G, Balague F. Backpacks and spinal disorders in school children. Eura Medicophys. 2004; 40(1): 15–20.
14. Negrini S, Politano E, Carabalona R, Tartarotti L, Marchetti ML. The backpack load in schoolchildren: clinical and social importance, and efficacy of a community-based educational intervention. Eura Medicophys. 2004; 40(3): 185–190.
15. Cottalorda J, Rahmani A, Diop M, Gautheron V, Ebermeyer E, Belli A. Influence of school bag carrying on gait kinetics. J Pediatr Orthop B. 2003; 12(6): 357–364.
16. Chow D, Leung K, Holmes A. The effects of load carriage and bracing on the balance of schoolgirls with adolescent idiopathic scoliosis. Eur Spine J. 2007; 16(9): 1351–1358.
17. Vitiello A, Pollard H. Backpack design: the use of ratings of perceived exertion (borg scale) – a review. Chiropr J Aust. 2002; 32(3): 91–98.
18. Ismaila SO, Oriolowo KT. Determination of safe backpack mass for students in tertiary institutions. Proceedings of the 2015 International Conference on Industrial Engineering and Operations Management; March 3–5, 2015; 2526–2529; Dubai, UAE.
19. Steele E, Bialocerkowski A, Grimmer A. The postural effects of load carriage on young people – a systematic review. BMC Musculoskelet Disord. 2003; 4: 2.
20. Drzał-Grabiec J, Truszczyńska A, Rykała J, et al. Effect of asymmetrical backpack load on spinal curvature in school children. Work. 2015; 51(2): 383–388.
21. Minghelli B. Musculoskeletal spine pain in adolescents: Epidemiology of nonspecific neck and low back pain and risk factors. J Orthop Sci. 2020; 25(5): 776–780.
22. Sturdy J, Rizeq HN, Silder A, Sessoms PH, Silverman AK. Walking slope and heavy backpack loads affect torso muscle activity and kinematics. J Electromyogr Kinesiol. 2023; 70: 10279.
23. Stücker R. The growing spine: normal and abnormal development. Orthopäde. 2016; 45(6): 534–539.
24. Beynon AM, Hebert JJ, Lebouef-Yde C, Walker BF. Potential risk factors and triggers for back pain in children and young adults. A scoping review, part II: unclear or mixed types of back pain. Chiropr Man Ther. 2019; 27(1): 61.
25. Hirsch L. Kids Health. Backpacks. Nemours Foundation. https://kidshealth.org/en/kids/backpack.html. May 2020. Accessed August 21, 2022.
26. Jones GT, Macfarlane GJ. Epidemiology of low back pain in children and adolescents. Arch Dis Child. 2005; 90(3): 312–316.
27. Reneman MF, Poels BJJ, Geertzen JHB, Dijkstra PU. Back pain and backpacks in children: biomedical or biopsychosocial model? Disabil Rehabil. 2006; 28(20): 1293–1297.
28. Brattberg, G. Do pain problems in young school children persist into early adulthood? A 13-year follow-up. Eur J Pain. 2004; 8(3): 187–199.
29. IBM Corp. (2021). IBM SPSS Statistics for Mac, Version 28.0. Armonk, NY: IBM Corp. [Computer software].
30. Beynon AM, Hebert JJ, Lebouef-Yde C, Walker BF. Potential risk factors and triggers for back pain in children and young adults. A scoping review, part I: incident and episodic back pain. Chiropr Man Ther. 2019; 27(1): 58.
31. Szpalski M, Gunzburg R, Balagué F, Nordin M, Mélot C. A 2-year prospective longitudinal study on low back pain in primary school children. Eur Spine J. 2002; 11(5): 459–464.
32. Perrone M, Orr R, Hing W, Milne N, Pope R. The impact of backpack loads on school children: a critical narrative review. Int. J. Environ. Res. Public Health. 2018; 15(11): 2529–2554.
33. Rodriguez-Oviedo P, Ruano-Ravina A, Perez-Rios M, Garcia FB, Gomez-Fernandez D, Fernandez-Alonso A, et al. School children's backpacks, back pain and back pathologies. Arch Dis Child. 2012; 97(8): 730–732.
34. Rai A, Agarawal S. Back problems due to heavy backpacks in school children. IOSR JHSS. 2013; 10(10): 1–5.
35. Rai A, Agarawal S, Bharti S. Postural effect of back packs on school children: its consequences on their body posture. IJHSR. 2013; 3(10): 109–116
36. Noll M, Candotti CT, Nichele da Rosa B, Loss JF. Back pain prevalence and associated factors in children and adolescents: an epidemiological population study. Rev Saude Publica. 2016; 50: 31.

37. Mackenzie WG, Sampath JS, Kruse RW, Sheir-Neiss GJ. Backpacks in children. Clin Orthop Relat Res. 2003; 409: 78–84.
38. Ahlqwist A, Sällfors C. Experiences of low back pain in adolescents in relation to physiotherapy intervention. Int J Qual Stud Health Well-being. 2012; 7(1).
39. Schechter NL, Berde CB, Yaster M. Pain in infants, children and adolescents: an overview.2nd ed. Baltimore: Williams & Wilkins, 2003; 3–9.
40. Kjaer P, Wedderkopp N, Korsholm L, Leboeuf-Yde C. Prevalence and tracking of back pain from childhood to adolescence. BMC Muscoskelet Disord. 2011; 12: 98.
41. Alfvén G, Olsson GL. Långvarig smärta hos barn och ungdomar kan och bör behandlas. Problemet är vanligt och medför stort lidande [Chronic pain in children and adolescents can and should be treated. The problem is common and causes great suffering]. Läkartidningen. 2008; 10: 720–722.
42. Hong Y, Cheung C. Gait and posture responses to backpack load during level walking in children. Gait Posture. 2003; 17(1): 28–33.
43. Skaggs DL, Early SD, D'Ambra P, Tolo VT, Kay RM. Back pain and backpacks in school children. J Pediatr Orthop. 2006; 26(3): 358–63.

Table 1.
Sample characteristics and outcomes

Grade	**Total**		**7**		**8**		**9**		**10**		**11**		**12**	
Age range	11-17		11-12		13-14		14-15		15-16		16-17		17	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Height (cm)	162.9	10.1	154.3	8.9	155.0	7.4	157.7	5.7	165.9	9.3	166.5	6.7	173.1	6.1
BW (kg)	52.6	8.4	43.7	6.5	47.9	6.8	50.1	5.8	55.1	6.7	58.0	4.3	60.7	5.8
Backpack weight (kg)	8.1	1.5	8.0	1.7	8.3	1.6	8.8	1.3	8.9	0.7	7.7	1.0	6.8	1.0
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Backpack as a % of BW		15.4		18.3		17.3		17.6		16.2		13.3		11.2
Students carrying > 10% BW	225	75	49	98	46	92	47	94	44	88	28	56	11	22
Students carrying > 20% BW	52	17.3	22	44	18	36	10	20	2	4	0	0	0	0
Students reporting heavy backpacks	109	36.3	20	40	28	56	27	54	27	54	6	12	1	2
Students reporting pain	161	53.67	33	66	28	56	31	62	36	72	17	34	16	32

Note. BW = body weight