Association of Relative Backpack Weight With Reported Pain, Pain Sites, Medical Utilization, and Lost School Time in Children and Adolescents

ABSTRACT

BACKGROUND: There is debate about a 10% versus 15% of body weight cutoff point for safe weight of school backpacks. Estimation of the cutoff may be affected by use of survey methods and failure to assess pain experienced while wearing a backpack. Previous research also suggests that younger students and females are more at risk for developing backpack pain.

METHODS: Five hundred and thirty-one 5th- to 12th-grade Northern California students and their backpacks were weighed. Students were individually interviewed about how often they experienced pain while carrying a backpack, the site of their pain, and if the pain had interfered with school activities or led to medical care.

RESULTS: Data support the use of a 10% of body weight cutoff for safe use of backpacks for all grade levels. Younger students and females are more at risk due to relatively lower body weight while females also carry heavier backpacks than males. Greater relative backpack weight is associated with upper- and mid-back pain reports but not neck or lower back pain; it is also associated with lost school time, lost school sports time, and greater chiropractic utilization.

CONCLUSIONS: The 10% cutoff is recommended along with a variety of practical methods to help schools achieve that goal for middle and high school students.

Keywords: injury prevention; child and adolescent health; health policy.

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n the past few years, there has been growing concern among teachers, school administrators, parents, and health care professionals over the effect of school backpacks on spinal and shoulder problems in children and adolescents, \(^1\) particularly since over 40 million American students carry backpacks. \(^6\) These reports usually suggest that the backpack load of children and adolescents should not exceed 10-15% of body weight, with most suggesting a 15% cutoff. For example, the 15% cutoff is suggested by the American Chiropractic Association, the American Physical Therapy Association, and the American Academy of Orthopedic Surgeons. \(^1,3,5,6,8-15\) However, students at all ages often carry much heavier relative loads. \(^14,16-18\)

While research indicates that thousands of backpack injuries result yearly from factors other than carrying the backpack (e.g., tripping over them, taking them off improperly, straps getting entangled in bicycle gears, etc), \(^1,7,19\) the primary concern of many school personnel and parents is the long-term use of heavy backpacks as the routine method of carrying books and other articles to, from, and at school. Siambanes et al \(^20\) surveyed 3498 Southern California adolescents and found that 41.5% reported pain when carrying their backpacks, with 16.9% consulting a doctor for the pain and 16.1% reporting missing some school activity due to pain. Pain reports were associated with walking to school (but not with time spent walking to school) and with a higher relative backpack weight to student weight. Thirty-one percent of boys and 42% of girls who carried a relative weight of 15% reported pain or more. Korovessis et al \(^21\) studied a sample of 3141 Greek students between the ages of 9 and 15 years. They reported that dorsal pain increased with increasing weight of backpacks. The authors did not analyze for relative backpack weight but found no effect of student weight as a variable on pain reports. Dorsal pain attributed to backpacks was highest for children aged 11 years, with 72% of girls and 38.5% of boys reporting pain. Lockhart et al \(^19\) studied 127 New England seventh-grade students. Almost 25% reported difficulty in carrying backpacks due to pain, while 31% reported problems in participating in a school or leisure activity due to backpack pain. Sheir-Neiss et al \(^22\) found in a sample of 1122 students that reported pain and impaired physical functioning increased with increasing degree of backpack usage and greater relative weight.

There is little evidence concerning the relationship between the method of carrying the backpack (1 or 2 shoulders) and reported pain. \(^6,19\) Korovessis et al \(^21\) reported no relationship with dorsal or low back pain, while Korovessis et al \(^18\) found in a sample of 1263 students that asymmetric carrying was correlated with higher intensity of pain reports; again, girls were more likely to report higher pain levels. Gender differences in backpack pain research seem consistent with the general finding that for the same intensity of painful stimuli, females are more likely to report higher levels of pain than males, a finding usually interpreted as reflecting cultural and contextual effects, \(^20,23,24\) though not every study finds gender differences in backpack-associated back pain. \(^5,12\)

One possible problem with the research literature on back pain and backpack usage is its reliance on questionnaires to assess pain, backpack usage factors, and other variables. In addition, students have not typically been asked to rate the pain they feel while wearing their backpacks or if they attribute their pain to backpack use or not. Typically, global back pain ratings (current pain or pain history) are correlated with backpack features. \(^5,12,17,19,22,25\) The use of global ratings could lead to an underestimation of the association between relative backpack weight and pain if previous pain reports reflected pain caused not only by backpack use but also by other possible factors, thus increasing measurement error variance and thereby reducing the estimate of the true association of backpack weight and pain. \(^22\)

Further, there is evidence that appropriately interviewing children about subjective states yields more reliable and valid responses than do questionnaires, due to more focused attention, exploration of the meaning of responses, and other factors. \(^26,27\) It might be argued that interviewing students, rather than assessing their pain experience through a questionnaire, would affect responses in several possible ways as responses would not be confidential. However, in most published research on backpack-associated pain, guarantees of confidentiality are absent or not specified if they were present. \(^5,19,20,22\)

Because of these problems, we adopted a brief one-on-one interview method that included self-report of pain while wearing a backpack. This method could reduce measurement error and improve validity, which then allows us to assess the effect of the usual questionnaire method on previous research results. If our method does reduce error, we might find a lower cutoff rate, while if our brief interview method yielded a higher cutoff, then policy makers and researchers would have greater assurance that previous results are not unduly contaminated by reliance on questionnaire methods or by global assessment of pain. This is particularly important when determining cutoff points for relative backpack weight since, as indicated above, there is debate about whether this cutoff should be 10% versus 15% of the child’s weight or even higher. \(^20\)

Based on previous research and the considerations above, we investigated the following: Is 10% or 15% of relative backpack weight a better recommendation in order to reduce backpack pain? Is there evidence that recommendations for relative backpack...
weight should be different for different grade levels or for boys versus girls? Is there any evidence that relative backpack weight predicts to interference with school activities or to use of medical services?

METHOD

Participant Selection

Five hundred and thirty-one students in 5 different Northern California public schools were recruited by first getting approval of the Superintendents of Schools of the 4 highest enrollment school districts in our semirural area. Policies of each district regarding research with students were followed. Selection of schools was guided by the desire to have schools that represented a diversity of socioeconomic statuses. There were 3 high schools (grades 9-12, ages 13-18) and 2 middle schools (grades 5-8, ages 8-13) selected. The principals of each school then chose which classes could participate based on considerations of class scheduling, availability, and convenience. Following school policy, in 2 classes (grades 7 and 8), the teacher required parental permission resulting in approximately 70% participation rate; in all other classes, all students attending class the day of data collection participated. Since this study was conducted by 2 private practice professionals (M.J.M. and D.L.M.), there was no university-based institutional review board approval.

Data Collection

Students were assessed at the various schools over a period of 18 months. On the day of data collection for a particular class, students were asked to bring their backpacks for weighing with the books and materials they typically carried to and from school. Students were only told that the study was about “the effects of carrying backpacks” with no other information provided. For purposes of this study, a backpack was defined as a bag having 1 or 2 shoulder straps (almost all were 2 shoulder straps) that could be carried on the back. All students participating from any particular school were assessed on the same day, minimizing the chances that students who had been assessed might influence later reports of other students.

Each student was weighed both with and without the backpack on using a Taylor lithium electronic scale. Musical instruments and sports clothes were excluded. Some previous research had included such items when assessing backpack weight, but in the surveyed schools, only a small percentage of students ever carried musical instruments. Also, when students carried musical instruments and sports items, they almost always did not place them in backpacks, but carried them separately by hand in instrument cases or in sports bags.

Backpacks were weighed only once. Previous research has found substantial variability in backpack weight depending on day of measurement. However, since the days of measurement were chosen by teachers and since measurement was conducted intermittently for 18 months on different days of the week, it is reasonable to assume that possible daily variability in backpack weight is a random factor which would add only to error variance, which would lead to underestimation of the magnitude of effects.

Measures

Relative Backpack Weight. For purposes of analysis, relative backpack weight was calculated as a percentage of student weight.

Subjective Pain and Pain Site Reports. After weighing, each student was individually interviewed by the researcher (M.J.M., a doctor of chiropractic), who had been identified as a “doctor.” Students were first asked, “Do you experience pain when you carry your backpack?” If a student responded “yes,” she or he was then asked, “How often do you experience pain when you carry your backpack?: 25% or less, 25% to 50%, 50% to 75%, or 100% of the time.” There were very few students who asked for clarification of this scale and almost all responded quickly. Students who reported pain more than 25% of the time were scored as pain reporters; all others were scored as nonreporters. (Unfortunately, the different pain frequencies were combined for the reporting students, requiring use of categorical data when conducting nonreporter versus reporter analyses. Very few students indicated pain 100% of the time; almost all pain reporters reported pain somewhere between 25% and 75% of the time.) The decision to score those reporting pain less than 25% of the time as nonreporters was based on clinical experience and some research evidence that the affective level of pain may be overreported as a result of an acquiescent response set toward medical authority. We also wanted to use a scale that could easily be adopted by teachers, not requiring specialized questionnaires, research scales, or exploration of the specific locus of backpack pain.

Pain reporters were next asked to indicate the location of their pain. After necessary clarifications by the interviewer, responses were coded by the interviewer as presence or absence of pain in 4 areas: neck, shoulders and upper back, mid back, and lower back. Very rarely did a student indicate pain in another area.

Pain Impact on Medical Utilization and Lost School Time. Pain reporters were then asked the following questions, each requiring a “yes” or “no” answer: “Have you had chiropractic care for your pain?”, “Have your had other medical treatment for
your pain?”, “Have you lost school time because of your pain?”, “Have you lost time from school sports because of your pain?”, and “Have you lost physical education time because of your pain?”. After answering these questions, each student was given an educational sheet on tips to reduce backpack weight, thanked, and dismissed.

Data Analysis
All analyses were conducted using Windows version 13.0 of the Statistical Package for the Social Sciences (SPSS). For descriptive purposes, percents, means, and standard deviations were calculated. Inferential analyses included $t$ tests, chi-square tests, analysis of variance, and stepwise discriminant function analysis. Tests of significance used a significance level of $p < .05$.

RESULTS

Sample Characteristics
There were 287 females (54.0% of the sample) and 244 males (46.0%). The percentages of participants in grades 5-12 are 11.9%, 8.5%, 10.5%, 11.1%, 17.9%, 30.1%, 5.6%, and 4.3%, respectively. Student weight ranged from 29.9 to 123.5 kg (mean = 59.8, $SD = 15.8$). Ethnicity of students was not recorded. However, the school districts’ records for the period of the study indicated that in all districts 92% or more of the student populations were non-Hispanic White. Hence, due to the monoethnic nature of this semirural sample, the small number of minority students precluded meaningful analyses of group differences.

Relative Backpack Weight, Gender, and Grade Level
Relative backpack weight ranged from 1.8% of body weight to 33.3% (mean = 10.7%, $SD = 4.5$). Analysis of variance of relative backpack weight as a function of gender, grade level, and their interaction showed that females had a higher relative backpack weight than males (means = 11.3% vs 9.9%, $SDs = 4.3$ and 4.7), $F(1, 515) = 8.47, p < .005$. The higher relative backpack weight for females resulted from females having both lower weight (means = 56.6 vs 62.6 kg, $SDs = 13.4$ and 17.4), $t(529) = 2.2, p < .03$, and heavier backpacks (means = 6.2 vs 5.8 kg, $SDs = 2.1$ and 2.3), $t(529) = 4.4, p < .001$. There was also a significant effect of grade level (means for 5th-12th grades = 12.1%, 12.0%, 12.0%, 12.1%, 9.5%, 10.0%, 8.6%, and 9.8%, $SDs = 5.6, 5.4, 3.6, 4.5, 3.6, 4.6, 2.9,$ and 3.1), $F(7, 515) = 5.75, p < .001$. It should be noted that for the schools involved in the study, students graduate after grades 5-8 to attend high school at grades 9-12. Based on the observation that the percentages were uniformly higher for the first 4 grades than the last, a simple post hoc analysis was performed that showed that the relative backpack weight was greater for grades 5-8 (mean = 12.1%, $SD = 4.8$) than grades 9-12 (mean = 9.7%, $SD = 4.1$), $t(529) = 6.2, p < .001$. This difference in relative backpack weight results from lower weight for the younger students (means = 52.0 vs 64.7 kg, $SDs = 14.2$ and 14.4), $t(529) = 10.1, p < .001$ as there was no difference between age groups in backpack weight (means = 5.97 vs 6.03 kg, $SDs = 2.2$ and 2.3).

Pain Report Predictors
Two hundred and sixty-one participants, or 49.2% of the sample, were scored as pain reporters, and 270 were nonreporters. As expected, pain reporters had higher relative backpack weight (mean = 11.4%, $SD = 4.3$) compared to nonreporters (mean = 9.9%, $SD = 4.7$), $t(529) = 3.85, p < .001$.

Gender and Grade Level. Ninety-five males (38.9%) and 166 females (57.8%) were scored as pain reporters. This gender difference was significant, $\chi^2(1) = 18.86, p < .001$. Pain report was associated with grade level for both females, $\chi^2(7) = 20.3, p < .005$, and males $\chi^2(7) = 44.8, p < .001$. Examination of the data did not reveal a linear relationship for either gender between likelihood of pain report and grade level. For males, the percentages of subjects who reported pain in grades 5-12 were 56.7%, 40.7%, 78.5%, 45.8%, 36.0%, 16.7%, 33.3%, and 37.5%, respectively. For females, the percentages of pain reporters were 39.4%, 50.0%, 87.5%, 45.8%, 36.0%, 16.7%, 33.3%, and 40.7%, 87.5%, 45.8%, 36.0%, 16.7%, 33.3%, and 40.7%. One possible cause of gender variability across grade levels is differential onset of puberty. Korovessis et al21 reported that for both boys and girls, higher levels of pain were reported immediately before and after onset of puberty. In this study, the highest percentage of pain reporters for males was for grade 7 (87.5%), with a mean age of 12.2 years. For females, the highest percentage was for grade 12 (86.7%), with a mean age of 17.3 years. Since onset of puberty is generally later than this for males and earlier for females for American students (mean menarche 12.8 years, mean spermarche is 13.0 years30), our findings are consistent with those of Korovessis et al, especially for females.

To further investigate pain variability among grade levels, a stepwise discriminant function analysis using Wilks’ lambda as criterion was performed with pain report as the grouping variable and relative backpack weight, gender, and grade level as predictors. Significance for a predictor to enter the equation was $p < .05$. Box’s $M$ test indicated equality of covariances (mean = 3.08, $ns$), indicating validity of comparisons of predictor coefficients. Results indicated only 1
significant equation (eigenvalue = .06). Standardized canonical coefficients were .72 for gender (females reported more pain than males) and .60 for relative backpack weight; grade level did not enter the equation. The canonical correlation was .23. These results indicate that once gender and relative backpack weight were accounted for, grade level did not predict pain reporting. The apparent variability among grade levels for each gender reported above appears due to factors other than grade level covarying with gender and backpack weight.

**Pain Site and Relative Backpack Weight**

Of the 261 pain reporters, 15.7% (41) indicated pain in the neck region, 37.2% (97) in upper back or shoulders, 12.3% (32) in mid back, and 27.6% (72) in lower back. Associations among pain sites were assessed by \( \chi^2 \) analyses. Only neck and mid back pain were significantly associated, \( \chi^2(1) = 4.25, p < .05 \) (2 sided), with the contingency coefficient = .13. Only 10.5% of those with no neck pain had mid back pain, while 22.0% of those with neck pain reported mid back pain as well. The lack of association among most sites as well as the small contingency coefficient suggest that the association between relative backpack weight and pain site should be assessed for each site.

In order to do this, independent t tests were conducted using percentage backpack weight as the dependent variable with comparisons between those reporting pain at a site and the 270 students who had reported no pain from backpack usage. Compared to nonreporters (mean = 9.9%, \( SD = 4.7 \)), students who reported upper back pain had greater relative weight (mean = 11.8%, \( SD = 4.1 \)), \( t(371) = 3.49, p < .001 \), as did students with mid back pain (mean = 11.4%, \( SD = 5.2 \)), \( t(306) = 1.68, p < .05 \). Those reporting neck pain or low back pain did not differ from nonpain reporters in percentage weight. A simultaneous regression analysis with percentage backpack weight as the criterion, using presence (present or absent) of pain at each of the 4 pain sites as predictors, yielded similar results with \( \beta \) for the presence of upper back pain = .11 (\( p < .01 \)) and \( \beta \) for the presence of mid back pain = .05, \( p < .07 \). Both the univariate and the multivariate analyses indicate that percentage backpack weight is associated with upper and mid back pain but not neck or low back pain.

**Association of Relative Backpack Weight and Pain on Medical Utilization and Lost School Time**

Nearly a quarter (21.5%) of pain reporters said that they had had chiropractic care for their pain, and 2.3% reported other medical treatment. Some 4.2% indicated that they had lost school time, 9.2% had lost school sports time, and 6.9% had lost physical education time due to backpack-related pain. Considering all reports of lost time, 13.4% of pain reporters said that they had lost time in 1 or more activities due to their backpack-related pain. There were no significant gender differences in the likelihood of these reported consequences.

For pain reporters, relative backpack weight was greater for those who had received chiropractic care (mean = 11.8%, \( SD = 4.3 \)) versus those who had not (mean = 10.0%, \( SD = 3.8 \)), \( t(259) = 2.55, p < .01 \); those who had lost school sports time (mean = 11.6%, \( SD = 4.3 \)) versus those who had not (mean = 9.7%, \( SD = 4.1 \)), \( t(259) = 2.13, p < .05 \); and those who had lost school time (mean = 11.6%, \( SD = 4.3 \)) versus those who had not (mean = 8.0%, \( SD = 3.8 \)), \( t(259) = 2.72, p < .05 \). There were no differences in relative backpack weight among those few pain reporters who had received other medical attention versus those who had not or those who had lost physical education time versus those who had not.

Among pain reporters, younger students (grades 5-8) were less likely to have had chiropractic care than older students (grades 9-12), but this difference failed to reach significance, 14.5% versus 23.1%, \( \chi^2(1) = 3.15, p < .07 \). There were no grade-level differences in reports of going to a medical doctor. Older students (8.5%) were more likely than younger students (0%) to report lost school time, \( \chi^2(1) = 11.57, p < .001 \). Older students (14.6%) were also more likely than younger students (3.8%) to report lost school sports time, \( \chi^2(1) = 9.11, p < .003 \). They were as likely as younger students to report lost physical education class time, 6.2% versus 7.6%, \( \chi^2(1) = .22, ns \).

**DISCUSSION**

This sample of 531 children and adolescents provides additional evidence for the association between relative backpack weight and pain reports. Further, our data suggest that 10% of relative backpack weight may be a better criterion than the 15% cutoff, which is widely recommended. Almost half of our sample (49.2%) reported pain while wearing a backpack, and pain reporters had a relative backpack weight of 11.4% versus 9.9% for nonreporters. Further, the risk of back pain was not affected by grade level over the 8 grade levels of our sample after controlling for gender and relative backpack weight. Hence, a 10% cutoff seems to apply in this sample for grades 5-12. In this regard, younger students are at greater risk as they weigh less than older students while carrying the same loads as older students.

Additional data support the 10% cutoff. When there are significant differences in the impact of back pain on medical utilization and lost school time, in all cases the disadvantaged students had relative
weights from 11% to 12% while the advantaged students had relative weights from 8% to 10%. Finally, the relative backpack weights associated with upper back and mid back pain were 11.4% and 11.8% versus an average of 9.9% for students who did not report backpack pain.

Since we argue that our brief interview method was likely to yield a better estimate of the association of backpack weight and back pain, it is not surprising that our results support a lower cutoff rate than often suggested in the literature. To put this in perspective, the difference amounts to a mean of about 3 kg (6.6 lbs) for our sample, which is close to the weight of 1 or 2 school texts.

Consistent with other backpack pain studies and gender differences in other pain literature, females were more likely to report pain while they were wearing their backpacks. Females also carried a higher proportion of body weight than males, which is attributable to both their lower body weight and higher backpack weights compared to males. These results contrast with other studies indicating that the general incidence of back pain is lower in adolescent females than males. There is nothing in the data to suggest a lower percentage cutoff for females than males, but their heavier backpacks suggest that achieving that cutoff may be more difficult.

We found greater relative backpack weight associated with upper and mid back pain. Other studies have not differentiated pain sites. Some research has indicated an association or lack of it with lower back pain or dorsal pain. Our results are particularly striking since most back pain in adolescents and children is in the lumbar region. The impact of backpack load on upper and mid back may be due to changes in posture while wearing the backpack, leading to long-term effects on spinal curvature (kyphosis), spinal misalignment, and muscle splinting (protective contraction) or spasm in the mid and upper back and shoulders. There is evidence that backpack-related acute orthopedic injury is most frequently in the upper back and shoulders and that structurally the upper back and shoulders may be the most prone to injury due to chronic loads.

Consequences of greater relative backpack weight in this sample are the increased use of chiropractic care, loss of school time, and loss of participation in school sports. These results are broadly consistent with the few studies that have also assessed the impact of backpack-related pain.

**Recommendations**

Based on these and other results, we make the following recommendations and suggestions. First, limit backpack weight to 10% or less of body weight, regardless of grade, for middle and high school students. We note that any cutoff is arbitrary and that for students close to a cutoff, there will be relatively more false positives or false negatives than for those more distant from the cutoff. However, the 10% figure is easily remembered and would have a practical utility. Further, it is much lower than the 15% or higher rate that has often been recommended by researchers or health care organizations. Second, focus especially on girls’ backpack weight. Girls on average weigh less than boys but they carry heavier backpacks. Girls’ reports of pain therefore should not be merely attributed to gender differences in pain thresholds or greater emotional expressiveness. Third, focus on prevention in middle school children. They carry as much weight as older children and hence are more likely to report backpack pain due to relative weight and not necessarily to age differences in stamina or reduced social inhibitions about reporting pain. Fourth, consider backpack pain as an under-recognized factor in school absences, nonparticipation in school sports, or activity components of physical education.

Fifth, there is no indication that educational programs on their own will lead to changes in backpack use. We suggest that the following methods could be used in association with health education for students:

- Use backpacks with waist belt supports on backpacks to reduce compression weight load carried on spinal structures or teach students to wear their backpacks lower on the back.
- Use rolling backpacks.
- Restrict the size of backpacks students are allowed to have or arrange for discount purchases of smaller backpacks, thereby forcing lower loads.
- Take part in the National School Backpack Awareness Day sponsored every September since 2005 by the American Occupational Therapy Association.
- Near the start of the school year, sponsor contests within or between classrooms to see which students or classrooms can pack the lightest or pack to the 10% maximum load criterion.
- Have flyers and posters with pictures of contents that would amount to 10% weight loads for students of different weights; post these in classrooms and school entrances and deliver to parents.
- Have “weigh-ins” held periodically in classrooms or at school entrances.
- Reinforce the 10% criterion in classroom exercises or teaching in sciences, mathematics, or physical education.
- Have backpack relay races in physical education.
• Where possible, replace textbooks with electronic media or provide a second set of textbooks to be kept at home.
• Review school homework policies to reduce the necessity of carrying textbooks home.
• Provide textbook storage space in classrooms or lockers.
• Reduce noneducational materials carried in backpacks, which have been found to range from 10% to 30% of backpack weight.3,20

Limitations of the Study
One limitation is that the sample is semirural and monocultural. However, the pain prevalence rates and general pattern of results are consistent with those from other diverse samples. Another limitation is that all data are self-report and cross-sectional; while few studies are longitudinal,10 they are clearly more desirable in assessing causation. The study does not yield evidence about objective physical effects of long-term backpack use. Finally, as with all correlational data, the current results could be validated by experimental manipulation of relative backpack weight over differing periods of time using both subjective and objective measures.36,41

REFERENCES