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REVIEW ARTICLE

Impact of Overloaded School Backpacks: An Emerging Problem

João Barbosa[1], Mário C. Marques[1,2], Henrique P. Neiva[1,2], Catarina Santos[1], Luís Branquinho[3], Ricardo Ferraz[1,2,*] and Daniel A. Marinho[1,2]

[1]*Department of Sport Sciences, University of Beira Interior, Covilhã, Portugal*

[2]*Research Center in Sports Sciences, Health Sciences and Human Development, CIDESD, Covilhã, Portugal.*

[3]*Department of Sports, Higher Institute of Educational Sciences of the Douro, Penafiel, Portugal*

Abstract:

The possible adverse effects of overloading students' backpacks are a public concern and should be considered by the scientific and educational community. This topic has gained particular importance due to the childhood development process, which can increase the promotion of future disorders (*e.g.*, back pain, low back pain, spinal column deviations). In this brief review, we critically analyze the impact of excess load in students' backpacks and attempt to identify solutions that can be useful to minimize the effects of this problem. It is necessary to find a viable alternative to classic backpacks that can contribute to minimizing the effects of backpack loads on children.

Keywords: School, Children, Backpacks, Overload, Future disorders, Kinematic.

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1. PROBLEM DEFINITION

The potentially adverse effects of students' heavy backpacks are a public concern and must be considered by the scientific and educational community [1 - 3]. The approach that has been used to study this problem has been fundamentally based on the quantification of the load carried by students in their backpacks [4 - 6], kinematic analysis of the influence of backpacks on upright posture and walking [7 - 9], kinetic analysis by studying plantar pressure and Ground Reaction Forces (GRF) [10 - 13] and surveys on various potential influences on back pain [14 - 16]. Loads carried by students differ substantially between countries [4, 17, 18]. Several factors differ (*e.g.*, study methodology, observed school year/age), making it relatively difficult to compare them. However, one common conclusion has arisen: students carry excessive loads in their backpacks. This conclusion is based on the recommendation also shared by the World Health Organization [19] that children should not carry more than 10% of their weight [4, 16]. However, the conclusions of these studies are contradictory or inconclusive, and it cannot be affirmed with certainty that backpack loads are responsible for children's back pain; therefore, more studies are required. Kinematic analyses have focused primarily on spinal deformities, particularly changes in the neck, head posture [12, 20], and gait produced by the addition of the backpack. Regardless of the focus of the kinematic analysis, alterations in posture and gait were observed when backpacks were worn. Similarly, kinetic analyses have also demonstrated changes in plantar pressure and GRF [12, 21]. Such modifications, evaluated by kinematic and kinetic approaches, led to inevitable health concerns, mainly because the subjects are children. Studies have also demonstrated these effects when standing and walking; however, children also run and jump while wearing their backpacks and, therefore, interest in analyzing this type of situation has emerged. In fact, mechanical forces influence spine growth [22], and high loading rates can negatively affect bone health [8, 23]. These effects, associated with changes in posture and identified when carrying heavy backpacks, can induce alterations in the spine curvature [24 - 31] and increases in intervertebral disc compression [24, 25], which are particularly important because the childhood development process can lead to future disorders (*e.g.*, low back pain).

This review highlights the potentially negative impact of excessive students' backpacks loads and seeks to improve understanding of this problem and help develop solutions. To search for relevant publications, databases were used primarily (*e.g.*, Web of Science, Scopus, PubMed). Articles written in English, Spanish or Portuguese were considered regardless of the publication date. Primary ('student backpacks', 'backpack load'), secondary ('back pain in children') and tertiary ('gait

* Address correspondence to this author at Department of Sports Sciences, University of Beira Interior (Covilhã), Portugal, Convento de Santo António, 6201-001 (Covilhã) Portugal; Tel: +351 275 329 153; Fax: 00 351 275 329 183; E-mail: ricardompferraz@gmail.com

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backpack load', 'posture backpack load') keywords were used. 98 articles were initially analyzed. All articles that did not focus on the investigation or that were not directly related to the topic were excluded. According to this exclusion criterion, only 60 articles were considered relevant for analysis.

2. SUMMARY OF PREVIOUS RESEARCH: PATHOLOGIES ASSOCIATED WITH THE USE OF LOADS IN BACKPACKS

The effects of carrying academic backpacks have been a particular concern because they are considered relatively heavy [1, 26]. Hence, this area has been a specific focus of the scientific community [27]. However, previous research mainly examined the field of biomechanics and focused on posture (static or dynamic) and the forces produced and acting on children when standing or walking [28].

Researchers have sought to define a load limit to be carried by students in the school context, given that changes in posture were evident, and the impact on children's health has become increasingly clear. However, there is still no consensus for the load limit recommendation. Therefor, studies have focused on metabolic effects [29], cardiorespiratory changes [30], pain reported by children [4], possible physical disability [16], postural changes [12, 31, 32], activation of muscle [32], changes in gait [33] and GRF [12]. The results of these different approaches have produced various backpack weight-limit recommendations (*e.g.*, 10% of a child's body weight). This latter recommendation has persisted since 2004, after being suggested via a critical analysis carried out by Brackley and Stevenson [34]. Later, another study [29] concluded that there were no changes in the metabolic cost if children carried less than 10% of their body weight. However, Moore *et al.* [16], investigating elementary and high school students (*i.e.*, 8–18 years old), found that higher relative backpack weights were associated with reports of back pain. Changes in electromyography, kinematics and subjective scores [32] were also noted, as well as an increase in trunk flexion angle [31], which influences gait and general stability [33], when loads were above the recommended limit (*i.e.*, 10% of a child's body weight). Other recommendations have also been proposed in this context. Al-Hazzaa [4] suggested a limit of 5–10% of body weight to avoid pain (*e.g.*, shoulder and shoulder) in boys aged 6–14 years, whereas Daneshmandi *et al.* [30] proposed a limit of 8% of body weight for male students aged 12–13 years because this was the limit from which cardiorespiratory changes began to be observed. Another investigation [12] found that carrying a backpack with a load of 7.5% of a 10-year-old child's body weight was sufficient to change head posture and GRF.

In addition, it is essential to mention that several reasons can be the cause of the excess weight carried by the students, which can originate the development of the aforementioned pathologies. One of the main reasons is related to the school curriculum. This is because, according to a previous report [35], younger students do not pay much attention to the subjects they will take during the day, and so they carry all their books unnecessarily. Thus, the same study [35] suggests that parents can have a fundamental role in teaching their children not to take unnecessary material to school. Additionally, the fact that they carry full-water bottles from home can also contribute to increasing the weight of the backpacks as well as the change in social trends that today lead to the regular transportation of various electronic devices [36].

However, even with these guidelines, it seems that there is still no recommended limit that meets consensus worldwide, and further investigations continue to be carried out to define the ideal load limit that should be carried by children [26]. Nevertheless, the possibility of not finding a universal limit has already been raised, taking into account each child's individual characteristics and existing anthropometric profile diversity [27]. Based on current findings, the recommendation of 10% of body weight as a load limit seems, however, to be the most appropriate.

3. EXPLANATION OF SUBJECT MATTER: THE EFFECT OF LOAD VARIABILITY ON SCHOOL BACKPACKS

Perhaps because there is no universal recommendation for this weight limit, parents and students do not control the weight of the backpacks and, generally, students carry more than 10% of their own weight. This observation was noted in New Zealand [17], and Ireland, where only one third of students carried backpacks that were within the 10% body weight guideline [14], as well as in the USA, where most students carried more than 10% of their body weight, and 5% carried more than 20% of their weight [5]. In Saudi Arabia, the 10% body weight guideline was exceeded by almost half of the sample [4]. In Poland, the average weight borne by seven-year-old students was approximately 25% of their body weight, and 95.5% of students exceeded the 10% weight limit recommended by the Polish health authorities [18]. About half (54%) of 447 Italian students aged 6–10 years carried more than 15% of their body weight, and only 16.6% carried 10% or less [37]. Greek students aged 9–14 years carried an average weight of 12.4% of their body weight [38] and in Malta, 70% of students aged 8–13 years carried more than 10% of their weight [39].

It is important to note that the previous presented values are averages from each study. Negrini *et al.* [40] provided a different perspective; loads carried by students were measured on each of the five or six days of the week, and maximum loads of the week were considered. These authors reported that 34.8% of six-year-old Italian students carried, at least once a week, more than 30% of their body weight. Furthermore, two aspects have merited the interest of researchers: 1) the possible tendency of one of the genders to carry more weight than the other and 2) the influence of age on loaded weights. Regarding the first aspect, studies in Greece [38], the USA [16] and Iran [41] found that girls are more likely to carry heavier backpacks. However, this trend has not been corroborated in other researches [5, 17, 35, 40] and was even contradicted by a Polish study that observed a tendency for male and female students to carry slightly heavier school bags [18].

Student age can influence backpack weights [6, 17, 18, 36]. Despite the differences in the absolute carried weights observed in different countries and school organizations, younger children were found to carry more relative weight than older ones [6, 17, 36]. Even if younger children carried the same weight, they would be carrying a higher relative weight because they are smaller and lighter [37]. In this regard, a critical aspect of using a backpack is its possible relationship with back pain. In fact, 80% of children who reported low back pain blamed it on an excessive school backpack weight [42,43], and biomechanical factors, such as school backpack characteristics, have traditionally been associated with back pain in children and adolescents [2]. These data reinforce the concept that low back pain is more common among school-age children than previously believed [44]. Thus, back pain is evidenced as a health problem in school-age children. In this regard, the sedentary lifestyle is possibly one of the most important factors in determining back pain in school-age children [35]. In fact, a sedentary lifestyle, combined with a lack of physical activity, effectively contributes to a lower muscle tone in the back. Some previous studies [6, 45] have shown that an individual with back pain in adolescence is more likely to develop low back pain in adulthood or that heavy backpacks can cause muscle problems in the neck, shoulders and back, such as scoliosis. In addition, reports of low back pain during adolescence indicate that such pain may represent a risk factor in terms of becoming a pathology in adulthood [43, 44].

Despite a lack of evidence regarding some aspects, it is agreed that the transport of backpacks induces several kinematic and kinetic adaptations in posture and gait. Children have been observed to walk at a lower cadence when carrying their school load [10, 45 - 48]; Hong [49] had already noted such adaptations when observing that 10-year-old children carried at least 20% of their body weight, and Liew [28] documented a decrease in stride length but also an increase in walking pace.

Changes in the position of the head and trunk are two common adaptations when carrying excessive weight. When backpacks were loaded at 15% of body weight, significant changes occurred in head angle (reduction of craniovertebral angle or increase in anterior head position) [1, 7, 47]. Mossad [12] also observed this change because children aged 8 to 12 years carried at least 7.5% of their body weight; thus, the trunk increased its flexion angle (forward tilt) [28, 29, 47]. It was recommended that future backpack designs included lower loads on the spine because low load placement minimizes the postural adaptations of children on the trunk and head [47, 48].

Carrying a backpack can increase reactive forces on the soil and plantar pressure [10, 49], and this increase can be conditioned by the child's educational level [10]. The increase in GRF was noted while children carried a backpack weighing only 7.5% of their body weight [12]. Thus, the increased GRF may be responsible for the higher level of knee flexion observed at further distances and may be a strategy to compensate for the inability of the ankle dorsiflexors to attenuate the impact forces [50 - 53]. In fact, such protective behaviour, when carrying a backpack, can generate smaller relative magnitudes of impact and propulsive forces when compared to the 'no-load' condition [52]. The changes in walking speed and double support time described above could be used to not only maintain stability but also assist in shock absorption [53].

When carrying a backpack on a single shoulder, despite changes induced in the posture [54], the body adapts to the asymmetric placement of the load, finding a new dynamic balance that is not significantly different compared with the use of two handles [33]. These adaptations cancel out a possible increase in the loading rate, even in children with scoliosis [11].

The analysis of GRF based on backpack use is of substantial importance because high levels of GRF are commonly associated with several health problems, such as lower limb injuries [18], degradation of articular cartilage and injuries at the spine level [20]. Mechanical forces influence spinal growth [55], and high loading rates can negatively affect bone health [1, 21]. These potential influences have gained emphasis because it is children of growing age who primarily use backpacks on a daily basis.

4. NEW APPROACHES TO THE PROBLEM

It is a serious issue for children to be carrying excessive weight in their backpacks. Alternatives have appeared in order to minimize the effects of transporting heavy backpacks, and several models have been proposed. For example, 'BackTpack' places the load bilaterally on the user, with two large pockets at the hip. An analysis of this model demonstrated that although not equal to the 'no load' condition, the displacement of the 'BackTpack' load allowed users to maintain a more upright posture than the traditional backpack the trunk was more upright, and the distance from the head ahead was decreased; hence, this backpack appears to be a viable alternative. However, this model did not show differences in GRF levels compared to traditional backpacks.

A reduction in forward tilt was also noted [20] when testing a backpack model with rigid straps. This model is similar to a traditional backpack, except for the straps, which are used to provide flexibility [56]. Kim *et al.* [20] also described changes in head posture when carrying a double front/rear package (two similar packages, one at the rear of the trunk and the other anteriorly) and when carrying a modified double package (smaller anterior package at the chest level). The double pack was found to promote neck hyperextension when compared to the 'no load' condition, but the modified double pack had a positive influence, minimizing postural deviation by decreasing the anterior angle and the anterior distance of the head when compared to carrying a control backpack [20]. These kinematic advantages of the anterior/posterior system in terms of head angle and forward tilt decreases may be responsible for the differences noted in anteroposterior GRF levels, which involved a decrease in the need for anteroposterior propulsive force, when compared to a traditional backpack [48]. Ramadan *et al.* [17, 57] created a pack, similar to a life jacket, with a large pocket on the back and two small pockets on the chest. A lower level of muscle activity (abdominal and erector spine) was noted as well as less increase in heart rate and increased perception of comfort for all transported load levels.

Ren *et al.* [58] used level walking computer simulations to study the effect of a suspension backpack model. This analysis included linear elastic and linear damping components. The research was conducted based on adults and military material. The authors' calculations suggested that the decrease in suspension stiffness might offer biomechanical advantages, namely the decrease in GRF peak values. Rome *et al.* [59] further showed that the use of elastic ropes to suspend the load of a backpack structure reduced its vertical movement and, consequently, the vertical force on the conveyor; energy expenditure was also decreased when walking with the backpack. This result corroborates the previous suggestion that due to the load phase delay, backpacks with suspended loads can reduce muscle energy expenditure during the transition from single to double support modes [60].

CONCLUSION AND SUGGESTIONS FOR FURTHER RESEARCH

Despite attempts to create alternative backpack models, which can offer biomechanical and energetic advantages, it is not common for students to use any of these models. This issue is most likely related to the new models' differences compared to the classic models or because none of these models have aroused commercial interest. Therefore, it is critical to develop effective solutions that would not substantially modify the design of the traditional backpack and that could still bring biomechanical advantages; in particular, new model designs should favorably influence GRF in order to minimize the potential adverse effects described earlier in this review. However, to achieve this aim, it is necessary to determine the characteristics of the cargo typically carried by students. It would, therefore, be interesting to understand the impact of that same load on the GRF, and based on these data, seek a solution that can offer advantages to students without substantially modifying the design and appearance of the traditional backpack.

CONSENT FOR PUBLICATION

Not applicable.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

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