

# Effect of Backpack on Static and Dynamic Balance in Healthy School Children: A Comparison

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## Abstract

**Purpose:** To assess and compare static balance using Single limb stance test (SLST), dynamic balance using Paediatric reach test (PRT) and Star excursion balance test (SEBT) with backpack and without backpack in healthy school children

**Method:** 150 healthy school children between 10-14 yrs were assessed using SLST, PRT, SEBT with backpack and without backpack. The data was analysed using paired t test.

**Result:** The scores for all tests were significantly low while carrying backpack ( $p < 0.0001$ )

**Conclusion:** Balance abilities in healthy school children get affected while carrying backpack.

**Keywords:** backpack, balance, static, dynamic, school children

## Introduction

Backpacks are commonly used by almost all students, military personnel and hikers.<sup>1, 2</sup> Increasing homework, more number of textbooks, bigger size of texts, variety of objects to be carried to school has led to a significant increase in load to be carried at school.<sup>3,4</sup> Lack of storage space,<sup>3,5</sup> and increased travelling time along with this load has drawn attention of several researchers and regulatory authorities on ill effects of the backpack on school children.

Amount of weight carried by children in their backpack generally exceeds the recommended 10% body weight limit.<sup>6,7,8</sup> Backpack, when carried posteriorly, causes shift of COG posteriorly and higher, leading to forward trunk lean and forward head posture.<sup>7,9</sup> In children, who already have larger heads and higher COG as compared to adults, this causes further deleterious effect on postural system. An individual uses antigravity muscles while quiet standing, ankle strategy while reaching in front or back within BOS and stepping strategy while going out of BOS.<sup>10</sup> With this added weight and altered biomechanics, these systems get challenged, which may lead to altered balance.

With today's changing scenario the children have to travel alone in public transport or on cycles or walking to reach to the schools. Heavy backpacks, challenged balance control system, along with heavy traffic and changing surroundings may increase the risk of falls in these children.

A lot of emphasis has been given to postural changes<sup>9,7,11</sup> and pain<sup>12,13,14</sup> due to backpacks, but altered balance issues in daily life due to backpack have been comparatively ignored, hence this study was designed with objectives of assessing and comparing the balance scores using SLST (Single leg stance test), PRT (Paediatric reach test), SEBT (Star excursion balance test) with backpack and without backpack in healthy school children.

## Methods

**Design-** This was a quasiexperimental design where participants served as their own control. Chit method was used to decide the order of the measurements for participant carrying backpack or no backpack.

**Participants-** 150 participants (calculated from a pilot study with SD-5.62, alpha-0.05, beta-0.9) between 10-14 years, of both gender, with ability to attend all data collection sessions and whose informed consent

was provided by parents were selected for the study. Any child with a history of spinal cord injury or deformity, fatigue, history of ear infection, lower limb injury or deformities, visual and hearing impairments, inability to follow commands, any neurological conditions, pre-existing condition that prevented the child from carrying backpack or low back pain limiting use of backpack was excluded from the study.

### Outcome measures-

Single leg standing test (SLST)-Participants were made to stand barefoot and 2 ft away from the wall. They were asked to fixate gaze on given point at eye level and 20 ft away from standing point. They were made to have stance on one lower limb and the other lower limb flexed 90° at hip and knee with ankle in neutral, hands on hips. The time was noted from the moment of lifting the leg and stopped when the stance limb moved on the floor or foot touched down or participant's gaze moved away from target or participant kept the leg hooked at stance limb in spite of warning twice. 5 min of rest was given between each test. Mean of 3 readings was taken as final reading. This is the standard test used commonly for children and has reliability of 0.91 to 1.00.<sup>15</sup>

Paediatric reach test (PRT)- The participants were asked to stand with their regular shoes and stand. Foot positions were marked with masking tape and kept same for all trials. The examiner stood at back of the participant. The loop of the tape was put around the middle finger. They were asked to keep the arm at 90 degree forward flexion elbow straight and wrist in maximum neutral and move as far as possible without lifting the heels in front and maintain the position for 3 sec. Mean of 3 reading was taken as the final reading.

The difference between two positions was noted. The test has inter rater reliability of 0.54-0.88 and intra rater reliability of 0.50-0.93, concurrent validity ranged from 0.42-0.77 and construct validity ranged from -0.79 to -0.88.<sup>16</sup>

Star excursion balance test (SEBT) - The participant was asked to stand at the center of a grid laid on the floor with 8 lines extending at 45 degree increments from the center of the grid. They stood in center and reached as far as possible with one leg without lifting the stanced limb and touched the line with the most distal part of the foot and as lightly as possible. The subject returned to a bilateral stance while maintaining balance. 6 practice sessions were given. Final reach distance was measured from center to the most distal point on line touched. The test has validity ranging from 0.38 to 0.93<sup>17</sup> with value of 0.59-0.95 and 0.68-0.95 intra rater and inter rater reliability respectively.<sup>18</sup>

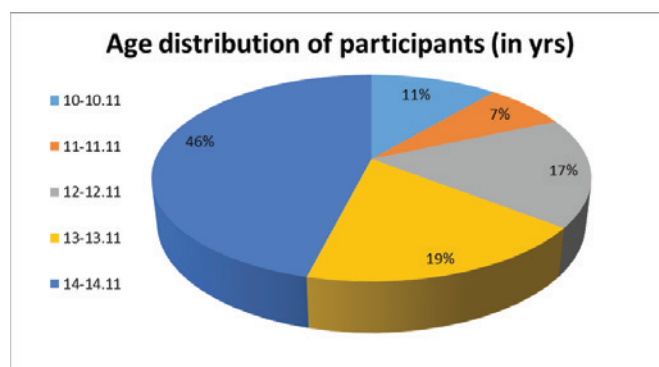
### Procedure-

IEC clearance and informed consent from parents was taken. Age, height, weight, weight of backpack of the participant were recorded. Chit method for recording with or without backpack served as a means of reducing condition induced bias. Daily backpack of participant was used as the load while taking readings with backpack. A rest of 10 minutes was given between each test. The sequence of SLST, PRT, SEBT was kept constant.

### Statistical Analysis

Demographic data was studied using descriptive statistics and other test results were compared by paired t test using SPSS 17.0.

## Results



Graph 1-

Graph 2-

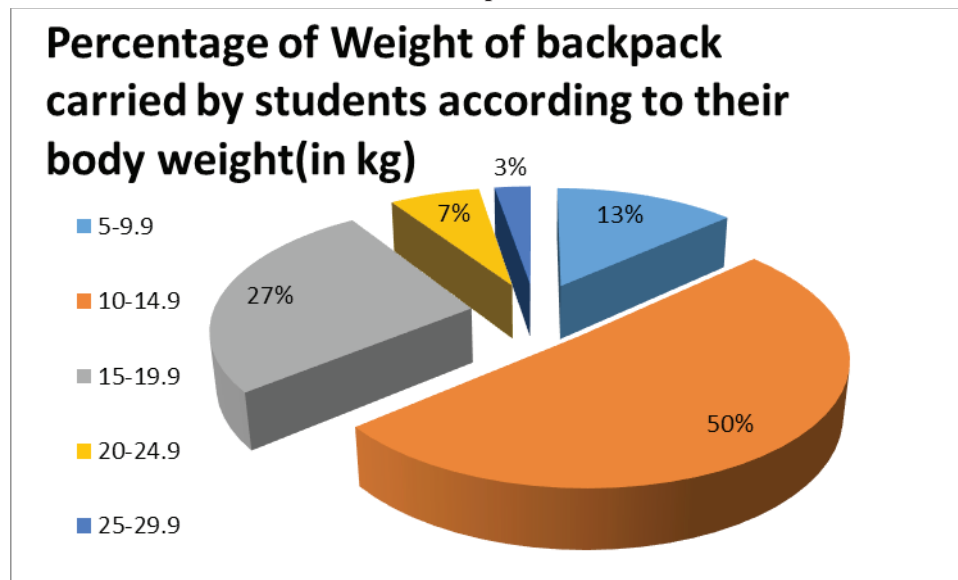


Table 1-COMPARISON OF SCORES WITH BACKPACK AND WITHOUT BACKPACK (using paired T test)

TESTS		Without backpack		With backpack		P value
		mean	SD	mean	SD	
SLST(cm)		131.97	54.65	96.80	40.44	<0.0001*
FRT(cm)		15.28	3.71	13.39	3.51	<0.0001*
SEBT (Directions)9(cm)	Anterior	42.63	6.87	39.99	6.44	<0.0001*
	Anterolateral	43.73	6.90	41.43	7.28	<0.0001*
	Lateral	42.21	8.13	45.43	12.11	<0.0001*
	Posterolateral	44.52	8.26	41.90	8.49	<0.0001*
	Posterior	42.79	8.51	39.89	8.16	<0.0001*
	Posteromedial	43.802	6.37	37.48	7.74	<0.0001*
	Medial	30.251	9.13	27.30	8.58	<0.0001*
	Anteromedial	40.613	7.94	38.08	7.84	<0.0001*

**Discussion**

Recommended weight limit for the backpack to be carried by children is 10% of their body weight.<sup>6, 7, 8</sup> 50 %of the children in this study carried backpack weighing more than 10 %of their body weight.

**EFFECT OF BACK PACK ON STATIC BALANCE-**

We used SLST with eyes open as a measure to assess static balance. Here, the COG lies lateral to S<sub>2</sub> vertebra so hip abductors and side flexors of trunk have

to contract to maintain the state of equilibrium in this position.<sup>19</sup>With backpack it shifts more laterally and above thus, challenging balance system. The participants showed significantly low scores for duration of single leg stance test while carrying backpack ( $p < 0.0001$ )

Very few studies describe single leg stance balance in healthy adolescents. No normative data was available for single leg standing with eyes open as most of the researchers used eyes closed in static condition and eyes closed and open in dynamic conditions to assess balance in healthy adolescents. We did not find any study assessing balance and effect of backpack on it using single leg stance hence no data was available for reference or comparison. But, this finding is in accordance with other researchers who studied the effect of load on static balance using postural sway.

One of the studies investigated modifications in sway parameters induced by backpack in Italian primary school children and found significant load induced increase in all sway parameters and linear relation between sway area and backpack weight. Since postural sway is an effective indicator of balance abilities, any alterations in it suggest that backpack carriage originates balance impairments.<sup>20</sup>

Similar findings were observed in another study on college students, where all the sway parameters increased in proportion to the weight added ( $p < 0.0001$ ).<sup>21</sup>

Study of effects of carried weight on random motion and traditional measures of postural sway was done in military soldiers using force plates. Here stabilogram analysis revealed that with increase in load the weight and center of excursion increased linearly but muscle activity changed minimally, suggesting that increased load challenged stability, reduced randomness of movement sway and made the load carrier exert greater control in order to maintain balance.<sup>22</sup>

Another study, on effects of external load on balance during upright stance, while examining the ability of new balance control model to predict those effects, also showed that, on application of external load, the COP mean velocity in A-P direction and RMS distance in M-L direction increased thus, concluding that external load affects balance and may lead to falls risk.<sup>23</sup>

## EFFECT OF BACKPACK ON DYNAMIC BALANCE-

Activities performed by children like reaching forward while playing imitates the PRT. The task causes displacement of center of gravity in forward direction by rotating around ankle joint with maintained hip extension, thus activating ankle and hip strategy. It has been observed that healthy individual activate ankle strategy for this task. Hamstrings work concentrically to control the forward tilt of the pelvis while Gastrosoleus work eccentrically to stabilize knee joint while reaching in front.<sup>24</sup> with added load of backpack COG shifted further anteriorly increasing the amount of force required to be generated by gastrosoleus. This in turn might have affected the reach distance. This theory was supported by the findings of our study where, the paediatric reach test distance was significantly low while carrying backpack ( $P < 0.0001$ ).

The other most commonly performed activity by children is jumping / hopping. Hence we chose SEBT as the other outcome measure for dynamic balance assessment. Here standing leg requires good range of motion at ankle dorsiflexion, knee flexion, hip flexion, adequate glutei and other antigravity muscle strength in order to control closed kinematic motion occurring while performing this task.<sup>25</sup> As the motion is performed in anterior, posterior, medial, lateral directions, it challenges gluteus maximus, medius, minimus, tibialis anterior, gastrosoleus. When there was increase in mass due to backpack, the COM moved up, distance from ankle to COM changed, weight of gravitational force on the mass increased, thus in turn, net muscle action required to maintain equilibrium also increased and made the situation more challenging for participants. This was reflected as decreased distance while performing SEBT with backpack ( $p < 0.0001$ ) in our study. Findings of this study are similar to the findings of one of the previous studies where significant changes in gait patterns and increase in trunk lean posture were observed when the load was increased to 15-20% of body weight of the child ( $p < 0.05$ ).<sup>26</sup>

Most of the previous researchers have used posturography or balance master to assess balance during dynamic conditions. As walking velocity and altered gait pattern indirectly represent the dynamic stability, we

tried to match these parameters with dynamic balance scores of this study.

One study showed significant difference in velocity control and directional control while carrying backpack in children.<sup>27</sup> Another study also highlighted back pack induced gait instability which resulted in significantly reduced walking velocity cadence and increase in double support time in adolescents with backpack weighing 20% of body weight of students.<sup>28</sup>

Study on effect of back pack on cervical and shoulder posture in students showed significant difference in cranio vertebral angle, anterior head alignment ( $p=0.04, 0.03$ ) and suggested that postural responses in high school children were sensitive to load carriage equivalent to 15% of body weight.<sup>29</sup>

Thus, this study strengthens the observations of previous researchers who concluded that, balance system gets challenged while carrying backpack due to change in center of mass and altered muscle work required to maintain equilibrium suggested by altered posture, affected gait quality and postural sway.

According to prior suggestions from APTA and ACA, the weight of backpack should be between 5%-15% of bodyweight of the child.<sup>30</sup> They have expressed concerns about heavy backpack, various aches and pains, risk of brachial plexus injuries. We suggest that, affected balance and hence risk of falls should also be one of the concerns while deciding backpack load in children.

Although the children could not be blinded for the experimental hypothesis of the study, independent evaluators performed tests for both conditions and the participants were blinded for their scores till scores for both conditions and scores of all participants were recorded. All tests in the study were performed on the same day hence effect of fatigue might have affected the scores. To avoid this, we kept the same sequence of tests and no inter test comparisons were done to draw conclusions. The weight of backpack varied in all students, but as the same student served as control this might not have affected the final results. We used quick and simple outcome measures to assess balance as it suited our scenario but, more sophisticated lab equipments, like posturography, can be used for complex analysis of activities while carrying backpack. The

study considered only immediate effects while carrying backpack. Similar studies on prolonged use and in different conditions will help us to strengthen evidence on effects of backpack on school children.

## Conclusion

Static and dynamic balance abilities get challenged while carrying backpack in healthy children of 10-14 yrs hence appropriate measures should be taken to reduce the impact of load thus reducing risk of falls in school children.

**Conflict of Interest** -Nil

**Source of Funding** –Self

**Ethical Clearance**-Institutional clearance was obtained.

## References

1. Wang Y, Pascoe DD, Weimer W. Evaluation of backpack load during walking. *Ergonomics*. 2001;44(9):858-869
2. Moore MJ, White GL, Moore DL. Association of relative backpack weight with reported pain, pain sites, medical utilisation, and lost school time in children adolescents. *J Sch Health*. 2007;77(5):232-239
3. Goodgold S, Corcoran M, Gamahe D, Gillis J, Guerin J, Coyle J. Backpack use in children. *Pediatr Phys Ther*. 2002;14:122-131
4. Mackenzie WG, Sampath JS, Kruse RW, Sheir-Neiss GJ. Backpacks in children. *Clin Orthop Relat Res*. 2003;409:78-84
5. Siambanes D, Martinez JW, Butler EW, Haider T. Influence of school backpacks on adolescent back pain. *J Peediatr Orthop*. 2004;24(2):211-217
6. Viry P, Creveuil C, marcelli C. Non specific back pain in children. A search for associated factors in 14-years-old school children. *Rev Rheum Engl Ed*. 1999;66(7-9):381-388
7. Pascoe DD, Pascoe DE, Wang YT, Shim DM, Kim CK. Influence of carrying book bags on gait cycle and posture of youths. *Ergonomics*. 1997;40(6):631-641
8. Nergini S, Carabalona R, Sibilla P. Backpack as a daily load for school children. *Lancet*. 1999;354(9194):1974

9. Cheung CH, ShumST, TangSF, YauPC, ChiuTT. The correlation between craniovertebral angle, backpack weights, and disability due to neck pain in adolescents. *J Back musculoske Rehabil.*2009;22(4):197-203
10. Shumway –Cook A, Woollacott M: translating research into clinical practice; Motor control posture and balance, Development of posture and balance ,ed-4. Lippincott Williams &Willkins, United states,2011;162,221-222
11. ChansirinukorW, WilsonD, GrimmerK, Dansie B.Effects of back pack on students:Measurement of cervical and shoulder posture.*Aust J Physiother.*2001;47(2):110-116
12. KistnerF, FiebertI, RoachKE.Effect of backpack load carriage on cervical posture in primary school children.*Work.*2012;41:99-108
13. WhittfieldJK,LeggsSJ,HedderleyDI.The weight and use of school bags in newzealand secondary schools.*Ergonomics.*2001;44(9):819-824
14. Burton AK,ClarkeRD, McClueTD,Tillotson KM. Theory of low back pain in adolescents. *Spine.*1996;21(20):2323-2328
15. Pamela K ,Sarah W Atwater, Terry K Crowe, Jean C Deitz , Pamela K Richardson. Balance Tests*PhysTher.* 1990; 70:79-87
16. Bartlett D, Birmingham T. Validity and reliability of paediatric reach test .*Pediatric Physical therapy .* 2003;15:84-92
17. ShaikhAA,Walunjkar R .Association between functional reach test and star excursion balance test in healthy children in healthy children of 14016 yrs. *IJCRR.*2014;5(23):01-05
18. Atiya A Shaikh,Radhika N walunjkar. Reliability of SEBT in children of 12-16 yrs. *IJPOT.*2014;8(2):29-33
19. Bohannon R, Lerkin P, CookA, Gear J, Singer J. Canada. Decrease in timed balance test scores with aging. *Phys Ther.*1984; 64(7):1067-70
20. Pau M, Pau M.Postural sway modifications induce by backpack carriage in primary school children. *Ergonomics.*2010; 53(7): 872-881
21. Rugelj D, SevsekF.The effect of load mass and its placement on postural sway.*ApplErgon.* 2011;42 (6):860-866.
22. Schiffman J,Bensel CK, Hasselquist L, Gregorczyk KN, Piscitelle L. Effects of carried weight on random motion and traditional measures of postural sway.*Applied Ergonomics.*2006.37(5); 607–614
23. Qu X, Nussbaum M. Effects of external loads on balance control during upright stance: Experimental results and model-based predictions.*Gait & Posture.*2009.29(1); 23–30
24. Wernick- Robinson M, Krebs DE, Giorgetti M M. America Functional Reach: does it really measure dynamic balance. *Arch Phys Med Rehabilitation.*1999;(80):262-269
25. Norris B, Trudelle Jackson E.Hip and thigh muscle activation during Star Excursion Balance Test. *Journal of Sport Rehabilitation.*2011;(20):428-441.
26. Hong Y, Cheung CK Gait and posture responses to back pack load during level walking in children. *Journal Gait and Posture.* 2005;17(1):28-33.
27. Palumbo N, George B, Johnson A, Cade D The Effects of Backpack Load on Carrying Dynamic Balance as Measured by Limits of Stability Work: A Journal of Prevention, Assessment and Rehabilitation.2001;16(2): 123-129
28. Singh T ,Koh M. Effects of backpack load position on spatiotemporal parameters and trunk forward lean. *Gait & Posture.*2009. 29 ; 49–53
29. Chansirinukor W, Wilson D, Grimmer K, Dansie B. Effects of back pack on students: Measurement of cervical and shoulder posture. *Aust J Physiother.*2001;47(2):110-116
30. American Physical Therapy Association. Back to school. <http://www.apta.org/news>.Published 2003. Accessed June 10,2005