

THE STUDENT BODY: THE EFFECT OF BACKPACK WEAR ON CENTER OF
MASS DISPLACEMENT IN COLLEGE STUDENTS DURING WALKING AND
STATIC STANDING

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ABSTRACT

THE STUDENT BODY: THE EFFECT OF BACKPACK WEAR ON CENTER OF MASS DISPLACEMENT IN COLLEGE STUDENTS DURING WALKING AND STATIC STANDING

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Objective: To investigate center of mass (COM) displacement during static standing and walking as well as forward flexion of the trunk during walking in college students in loaded and unloaded conditions. **Design and Setting:** All data were collected in Jowers Biomechanics Laboratory, Texas State University-San Marcos. **Subjects:** Subjects included 20 college students (ages = 22.85 ± 5.58 years, mass = 72.11 ± 11.28 kg, height = 169.89 ± 10.01 cm) with no reports of injuries to lower extremities in the last two years. **Measurements:** Participants stood on the Biodex Balance System static platform and performed postural stability tests. Subjects were then recorded walking for 5 meters, to measure movement of the hip. In both portions of the study, 3 trials were conducted in unloaded conditions, followed by 3 trials while carrying a backpack loaded to roughly 10% of subjects' weight. **Results:** One tailed and two tailed T tests were performed. A significant difference was found in the angle of trunk flexion ($t < .01$). Average angle of inclination at the trunk in unloaded walking was $165.56 \text{ degrees} \pm 6.75$ and $158.29 \text{ degrees} \pm 6.87$ during loaded walking. No significant difference was found in vertical COM displacement during walking or static standing between loaded and unloaded trials.

Conclusions: Based on these findings, this data indicates that trunk forward flexion while wearing a loaded backpack occurs in consistent correlation regardless of weight, height, weekly exercise frequency or velocity during ambulation in college students. It is also indicated, based on these results that a backpack loaded at 10% of an individuals' body weight does not affect the COM location compared to unloaded trials during static standing, or vertical COM displacement during ambulation.

CHAPTER I

INTRODUCTION

The human bodies' center of gravity or center of mass (COM) has been studied extensively to determine where exactly it lies in the human body and what, if any, effects occur due to a skewed center. Many individuals who suffer with gait deviations, physiologic deformities or major muscle weaknesses encounter problems with balancing due to a skewed center of mass [1]. The COM is an imaginary point at which the total body mass can be assumed to be concentrated and changes based on an individual's change in posture [2]. When the body is subjected to carrying an extra load, it is estimated that the COM position changes to compensate for the increased mass. Recent studies on the effect of backpack wear claim that backpacks can lead to injury based on weight carried, and backpack position. Cervical spine and shoulder injuries are commonly reported in literature as well [5]. Other studies have investigated the effects of COM and gait deviations in children who carry up to 20% of their weight [4]. However, literature has not been found on the effect of COM displacement in healthy adult college students carrying a relatively low weight backpack while standing and walking.

PURPOSE

The purpose of this study was to determine COM deviation in healthy, uninjured college students both while wearing a backpack and without wearing a backpack. During standing this will be measured based on center of pressure, or COP (the estimation of the movement around the COM due to contralateral muscle activation causing the COM to constantly be in motion) displacement on a static platform with the Biodex machine.

During walking, vertical COM displacement will be measured, as well as the angle about the hip.

RESEARCH HYPOTHESES

It is hypothesized that during the static standing portion of this study, The COM indicated by the COP on the Biodex Balance System will deviate toward the posterior quadrants and be more likely to deviate out of the 0-5 degree balance zone while the subjects are wearing the loaded backpack versus when they are not. During the walking portion of the study, it is hypothesized that the vertical displacement of the COM will be decreased in an attempt to increase energy efficiency. It is also hypothesized that during walking the angle about the hip will decrease while the subject is in the loaded condition.

OPERATIONAL DEFINITIONS

1. Center Of Mass (COM) - Also known as center of gravity. The point at which the total body mass can be assumed to be concentrated without altering the body's translational inertia properties.[1]
2. Static Standing- Standing on a stable surface, without movement.
3. Center Of Pressure (COP) - Used to index the amount of movement or sway of the center of gravity during stance, as the COM (even during static standing) does not stay "glued" to one position due to contralateral muscle activation necessary in order for the body to stay balanced. [6]
Generally indicated by the pressure of the feet on the surface. During static standing, is a rough estimation of COM.

4. Vertical Displacement - The amount on the y-axis that an object moves up or down. In this case COM vertical displacement is measured during walking.
5. Force plate - a machine that measures ground reaction forces of the body
6. EMG - (electromyography) measures electrical activity of muscles at rest and during contraction.
7. Sagittal - View from the side of the body.
8. Superior -Towards the head.
9. Inferior - Towards the feet.
10. Anterior - Towards the front of the body.
11. Posterior -Towards the back of the body.

ANATOMICAL LANDMARKS

1. 2nd sacral vertebrae - The second vertebrae of the sacrum. The sacrum is below the Lumbar spine. Rough location of the human body COM.
2. Iliac Crest - The curved, superior portion of the ilium.
3. Greater Trochanter - the most prominent bony structure on the side of the hip, inferior to the iliac crest. Used as a measure of COM during walking.
4. Lateral Femoral Condyle - most lateral and inferior bony prominence of the femur.
5. Subacromial Space - indentation between the most superior part of the shoulder (the acromion) and the head of the humerus.

BOUNDARIES

This study has certain boundaries that could affect both the collection and interpretation of data.

1. The subjects were between the ages of 18 and 40.
2. The subjects were used as their own controls.
3. The subjects were asymptomatic for lower extremity or neurologic injury/deficit at time of testing.
4. The subjects' response to questionnaire on injury status and physical activity level cannot be verified due to time constraints.

LIMITATIONS

This study has certain limitations based upon the collection processes and interpretation of the data. Conclusions based on the results of this study are limited based on the following

1. Results of this study cannot be applied to any person younger than 18 or older than 39.
2. Results of this study cannot be applied to any person suffering from a lower extremity injury of any kind currently or within the last two years.
3. Results of this study cannot be applied to individuals suffering from neurologic disorders.
4. Results of this study cannot be applied to situations in which a greater or lesser amount of weight is carried.

5. Results of this study cannot be applied to situations in which the backpack is carried in a different manner.

ASSUMPTIONS

1. The subjects that agree to participate in this study will be randomly selected.
2. It is assumed that subjects answered Questionnaire on physical activity level and injury status honestly and accurately to the best of their knowledge.
3. It is assumed that subjects do not know the full reason for the study in order to prevent conscious effort of stabilization of the body during the experiment.

SIGNIFICANCE OF THE STUDY

This study will attempt to determine if COM is affected by posterior load carriage of roughly 10% of body weight in college adults during standing and walking. Faulty biomechanics as a result of changes to the center of mass in the body may lead to instability or falls, and injuries of the back, shoulder and lower extremity. The study will compare COP during static standing as it relates to COM and correlate the unloaded trials to the loaded trials. This will aid in determining whether or not the body is compensating for the added forces placed on the body due to the backpack weight during the ambulation of the study, the angle about the COM at the hip will be measured during the loaded and unloaded trials in order to determine if carrying 10% of body weight will affect the stability of the body around its COM.

The experiment will additionally compare the results based on demographics such as height, weight, weekly cardiovascular physical activity level, and weekly resistance training frequency. The results of this study will aid biomechanics specialists and health professionals in understanding what happens to the human body when subjected to a posterior load. In the event that results are significant, measures can then be taken to prevent or treat injury in the higher education population. No other research study has been documented which compares the same factors in COM displacement as it is related to possible injury and pain based on these demographic factors.

CHAPTER II

REVIEW OF RELATED LITERATURE

Previous backpack related studies have commonly investigated the effects of gait and balance on children, military personnel [7], and individuals with lower extremity injury or pathological gait. Much of the research has been conducted using 10 - 20% of body weight in the backpack loads, especially in children and individuals with lower extremity injury or skeletal deformities. The effect of military backpack loads on military personnel have also been investigated at greater than 15% of body weight loads [7]. Backpacks have been found to cause injury to both shoulders and necks and have also been found to be responsible for forward flexion of the trunk[3], skewing center of mass in the body and placing undue stress on the spine and other structures.

Healthy, college adults wearing relatively light backpack loads have not yet been studied for COM displacement during static standing and walking. It is important to understand the effects of backpack loads on COM in this population because an increasing number of adults are opting to continue with higher education, and therefore backpack usage.

COM Location in the Human Body.

COM location in the body has long been disputed. Complicated equations have been developed which use the calculation of mass and length of each limb in order find the COM of each body segment in a certain individual. Laser diodes are then placed at the COM location for each limb and the lasers intercrossing point are considered the location of the COM for that individual. The calculation of force plate data using COP has also been used to find the approximate COM in the human body[14].

For the purpose of this study, COM will be estimated at just anterior to the second sacral vertebrae. Females have a slightly lower COM due to the wider pelvis. Males have traditionally been documented as having a slightly higher COM due to the higher amount of weight carriage in the upper body.

For the second portion of the study in which ambulation will be recorded, the COM will be marked at the 2nd sacral vertebrae by placing a marker below the iliac crest, at the location of the greater trochanter, to chart changes in COM vertically or changes in the angle about the hip [8] In this study, the rough estimate of COM will be used. The exact location of the COM is unnecessary to calculate displacement, and additional calculation required in calculating each participants COM would be extraneous.

Normal Biomechanics of COM during Static Standing

As mentioned previously, the COM in the human body is estimated to be located below the belly button, just anterior to the 2nd sacral vertebrae, or just below the crest of the ilium from the sagittal view. When an individual is motionless, or static, the COM will also remain motionless. When an individual moves or shifts body weight, the COM will change based on the demands placed on the body.

COM during static standing is often times calculated by the changes in COP or center of pressure. According to LaFond et al., the center of pressure (COP) oscillates on either side of the COM where the COP displacement always exceeds the COM. However, it has been found that in static standing situations, the vector generated by the force plate data of the COP points to the COM [11] During static standing and quasi static standing, COP has been determined to be nearly equivalent to COM.[12][13]

Postural control and balance are necessary components of stable COM. Neural proprioceptors in the muscles constantly send messages to the brain of where each section of the body is located in space . Muscles groups are then autonomically controlled to either contract or relax in order to maintain an upright position and posture of the body. This postural sway is a fundamental part of maintaining equilibrium around the COM of the body[19].

For individuals suffering from lower extremity injury or neural deficits, balance is challenging to maintain during static standing due to the constant movement of the COM as a result from perturbation of outside forces which weak muscles and compromised neural components are unable to control. This is especially prevalent in individuals suffering from chronic ankle sprains[20].

Normal Biomechanics of COM during Walking

There are two major cycles of gait during walking: the stance phase, which accounts for about 60% of the gait cycle, and swing phase, which represents about 40% of the gait cycle. The two phases are further broken down into sub-phases[21].

The stance phase is broken down in to 5 periods:

- I. Initial contact - in which the heel first strikes the ground,
- II. Loading response -where the body experiences contralateral support with both feet in contact with the ground,
- III. Midstance - in which the body weight is almost completely supported by the lead foot, the contralateral limb is supported only by the toes, called the toe off position.

- IV. Terminal stance - the lead foot completely supports the weight of the body (the other leg is off the ground in the swing phase.)
- V. Pre swing - the opposite foot is in initial contact, and the beginning limb is in the toe off position.

The Swing phase is broken down in to 3 periods:

- I. Initial swing -begins when toe comes off the ground and ends when knee is flexed to about 60 degrees.
- II. Midswing - occurs from the end of initial swing until the lower leg is perpendicular to the ground.
- III. Terminal swing - begins when the lower leg is perpendicular to the ground and ends with initial contact of the heel on the ground (the first period of the Stance phase.)

In order to maintain stability and balance while walking, the COM during gait doesn't simply stay in the same place during each period of the gait cycle; the COM displaces horizontally and vertically based on weight distribution changes during each phase. This translation of the body COM is a fundamental component of ambulation. According to Gard et al. normal human walking is characterized by a periodic vertical displacement of COM that moves through a complete cycle of vertical motion with each step, or two cycles during each stride [10]. The COM during ambulation reaches its highest point (peak) during the midstance phase [14]and its lowest point (trough) when COM passes from one foot to the other during the Loading Response Phase. [15] Normal vertical displacement is roughly 5 cm at self selected speeds. In a study conducted by Inman, research confirmed that the path of this cycle creates a sinusoidal curve [22] which has

been well documented in many additional research studies. This path is considered the most energy efficient system of ambulation and changes based on the velocity of walking speed. Therefore, as velocity increases, the vertical excursion also increases in order for proper transfer of forces and therefore efficient use of energy [16] [10] [15].

COM Changes While Wearing a Posterior Load

When a posterior load is added to the body, forward flexion of the trunk is increased in order to counteract the forces pulling the COM posterior. This forward flexion is necessary in order to maintain balance and neutrality of the body as energy efficiency [17]

Chow et al. [18] studied the effects to balance and posture that backpack load placed on school age girls with idiopathic scoliosis and normal controls. The study found a significant increase in anterior-posterior sway during COP measures in both groups of subjects. The study also determined that an increase in trunk flexion occurred for both groups, with the scoliosis group showing a more marked increase versus the normal group.

In a study conducted by Palumbo et al. [9], subjects were instructed to lean towards specific targets when prompted with a visual or auditory cue either with or without a backpack. The study concluded that movement velocity decreased in all directions while subjects were wearing a backpack versus when they were unloaded, suggesting a decline in directional control of the COP when subjects were wearing a backpack. A possible explanation for this bodily reaction may not just be due to the backpack's weight, but also due to the fact that COM adjustments needed to maintain stability may take more time for

compensation. If the body is unable to compensate for this perturbation caused by the abrupt movement and posterior load, the individual may experience loss of balance.

COM and Repetitive Stress Injury(RSI)

The COM is defined as the point at which the total body mass can be assumed to be concentrated without altering the body's translational inertia properties [2]. Balance at the point of COM creates greater stability and less stress on joints of the body. As humans move the body into varying positions, such as bending over to pick up an object on the floor, the location of the COM changes in order to maintain stability in the new position[23]. When the body posture is maintained in an awkward position- such as slumping while sitting at a computer or forward flexing while carrying a heavy posterior load- a repetitive stress injury or RSI may occur after a period of time.

Therefore, despite the change in COM during body movement, awkward postures and position have been shown to cause undue stress on the joints of the upper or lower body when weight distribution is changed. Backpacks have been well documented to cause RSI's to the neck and shoulders due to the compression caused on the shoulder joint by straps[26] and the forward flexion of the neck caused by the weight of the posterior load [25]

Neushwander et al. used MRI to measure how much disc compression children's' lumbar spine experienced with backpack loads increasing from 10% of body weight.

Compression of the Lumbar and thoracic spine was reported with all backpacks weights, with no significant difference between the degree of spinal compression and backpack load, indicating nearly equal amount of vertebral compression in all weighted loads[24].

This result leads to the conclusion that over time, no matter what percentage of body

weight was used the repetitive compression trauma placed on the spine due to posterior loads leads to possible stress injury of the intervertebral discs and may result in low back pain in children and possibly adults.

CHAPTER III

METHODOLOGY

The purpose of this study was to determine COM changes during loaded and unloaded walking relating to measures such as COP during static standing, COM vertical displacement during ambulation, and the angle about the hip during ambulation.

Subjects

The subjects (n=20) that completed the study were uninjured, college enrolled males and females (14 females, 6 males) between the ages of 18-39 years of age (age = 22.85 ± 5.58 years, mass = 72.11 ± 11.28 kg, height = 169.89 ± 10.01 cm) . Participants were undergraduate students recruited from the College of Health and Human Performance and the College of Education at the Texas State University campus in San Marcos, TX. For inclusion, participants must be an enrolled undergraduate at the University and have not had any injury to the lower extremity in the last two years. Physical activity level and gender were not excluding/including factors. Before participation in the study, participants filled out a brief seven question questionnaire detailing their age, weight, height, gender, cardiovascular exercise activity level, resistance exercise weekly frequency, and injury status. Participants then signed a consent form provided by the principal investigator, detailing the purpose and procedures of the study, along with a confidentiality clause. The principal investigator then detailed the procedures of the study to the participant and was available for any questions. All subjects were assigned a corresponding number in order to differentiate the results found between subjects and to maintain the confidentiality of the subject's information and results. All subjects

provided written informed consent in accordance with the Institutional Review Board at Texas State University-San Marcos.

Instrumentation

Testing for each subject was performed in one 20 minute session in the Biomechanics Lab located in the Jowers building at Texas State University- San Marcos. The lab included all required equipment: the Biodex Balance and Stability System, Slow motion camera, and Dartfish import software. Based on the participants' weight, a standard size, two strap backpack was filled to roughly 10% of the subjects' weight. The back pack was carried on both shoulders by the subjects, with the base of the backpack located roughly where the lumbar spine meets the sacrum. Participants were instructed to adjust the backpack to where the weight felt evenly distributed over both shoulders. The principal investigator checked to make sure that the base of the backpack and the shoulder straps appeared at equal heights.

The principal investigator was present for all aspects of data accumulation with subjects and conducted procedures based on step-by-step instructions.

PROCEDURES

Biodex Balance

For the first portion of the study, participants were asked to stand on the Biodex balance platform to assess COP and balance. Participants were first briefed on the procedures of this portion of the study. Participants were instructed to step onto the platform and to place their feet as wide as they would usually stand. The principal investigator then palpated the 5th metatarsal head of both feet and moved the foot either forward or

backwards so that the landmark would be over the midline of the platform and so that the feet were evenly placed. The principal investigator then marked where each foot was placed in order to ensure no discrepancy of foot placement between each trial. The principal investigator covered the Biodex screen which offers feedback on COP movements so that participants could not correct themselves. The principal investigator set the platform to static, and instructed the participant to stand still with hands by sides, looking straight ahead. The postural stability test was selected, followed by the participants' height range in inches. Timing began after the principal investigator received affirmation that the subject was ready and had not moved their feet. Each trial was timed for 30 seconds. After each trial, the subject was allowed to relax with hands on the side bars for 1 minute. After each trial, principal investigator received a print out of COP trajectory for each trial, and marked it with the corresponding subject number, trial order (a, b, c), and backpack status (U for unloaded, L for loaded.) Before the beginning of next trial, subjects' feet were checked for correct and consistent placement, and reminded to stay still and look forward during the 30 seconds. The Biodex Balance and Stability System force plate measures plane of COM location based on 4 quadrants (anterior right, anterior left, posterior right, posterior left) and concentric balance zones (0-5 degrees, 6-10 degrees, 11-15 degrees, 16-20 degrees). The optimal COM during static standing is located at the cross point of the 4 quadrants in the 0-5degree concentric balance zone. Based on the printouts from each trial, location of COM can be estimated and compared.

3 trials were performed with the subject not wearing a backpack (unloaded) and 3 trials were performed with the subject wearing a backpack with roughly 10% of subject's body weight (loaded).



Illustration 1. Biodex Static Standing in Loaded Condition

Ambulation Protocol

After the Biodex portion of the study, participants were briefed on the procedures of the ambulation portion of the study. The principal investigator placed a square of black athletic tape that could easily be seen from the camera on the subjects' dominant side at

the subacromial space and the lateral femoral condyle. A reflective bulb was placed on the dominant side greater trochanter of the participants. All landmarks were found via palpation conducted by the principal investigator.

Subjects were instructed to walk normally at their own self-selected pace on a straight line positioned at a right angle to the camera. Participants began 10 meters back from the camera in order to achieve an adequate pace and smooth rhythm. Only the last 5 meters of the walk was recorded on camera. A one-meter landmark was placed in front of the walking line in order to conduct data analysis.

Participants were told when to begin walking and the principal investigator began recording, and continued until the participant could no longer be seen on screen. The participants were recorded a total of 6 times consisting of 3 unloaded trials and 3 loaded trials. Between each trial the principal investigator checked the landmark markings to ensure consistent data collection.

Data was collected using Dartfish Software



Illustration 2. Unloaded Walking

CHAPTER IV

STATISTICS AND RESULTS

STATISTICS

Data analysis was performed using Excel Data Analysis (Microsoft Word, 2010) at a 95% Confidence interval (CI) significant (P value $<.05$). One tailed and two tailed T tests were performed for angle of trunk flexion, vertical displacement, and velocity correlations between loaded and unloaded backpacks. Pearson Correlation Coefficient was used in order to determine correlations for demographic statistics.

RESULTS

Static Standing

This study attempted to determine if there is any correlation between posterior load carriage and COM changes. COM changes were qualitatively analyzed for each of subjects 6 trials during the static standing Biodex portion of the study. All trials for each subject were compared for significant changes in COM location based on quadrant (anterior right, anterior left, posterior right, posterior left) and concentric area (innermost 0-5 degrees, 6-10 degrees, 11-15 degrees, 16-20 degrees outermost) between the loaded and unloaded assessment (see illustration 4). No significant difference between quadrant location and concentric zone was observed between unloaded and loaded trials in each subject.

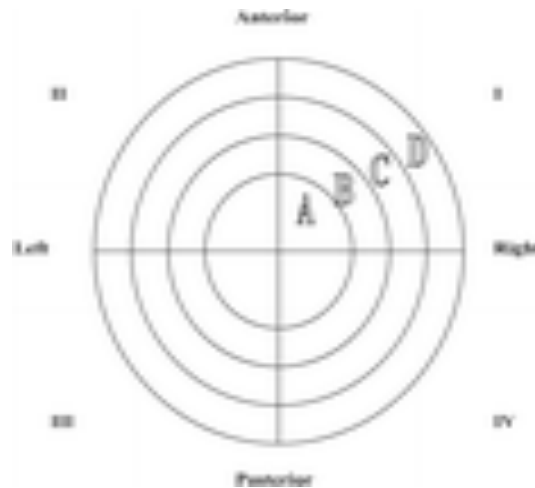


Illustration 3: Biodex quadrants and concentric balance zones. Source from <http://informahealthcare.com/doi/abs/10.1080/17483100802542868>

Angle of Trunk Flexion

Analysis of velocity, angle about the hip and vertical displacement of COM were all evaluated using the Dartfish software system. From each video recorded trial, the principal investigator calculated the angle of the trunk as the participant passed at a right angle to the camera. When the subject was in the heel strike with the side of the dominant leg facing the camera, the markers at the greater trochanter, subacromial space and lateral femoral condyle are connected to calculate the angle of the trunk flexion. Average angle of inclination at the trunk in unloaded walking was 165.56 degrees \pm 6.75. During loaded walking, angle of inclination about the hip averaged 158.29 degrees \pm 6.87.

One tailed T-test was performed ($t < .01$) along with the two tailed T- test ($t < .01$) and significant difference was found between unloaded and loaded walking for trunk angle flexion.

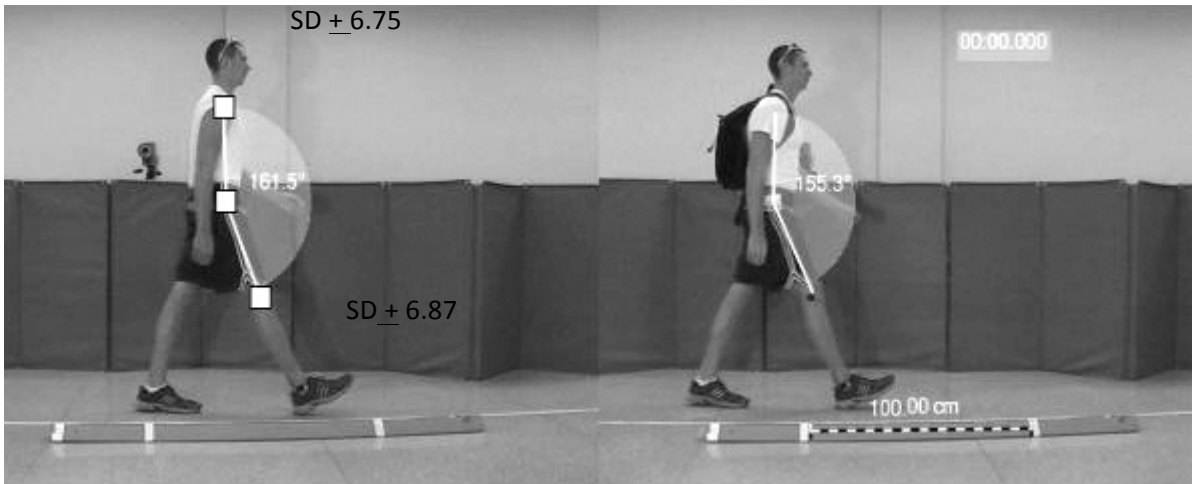


Illustration 4. Demonstration of Trunk Angle of Flexion Calculation Using Dartfish

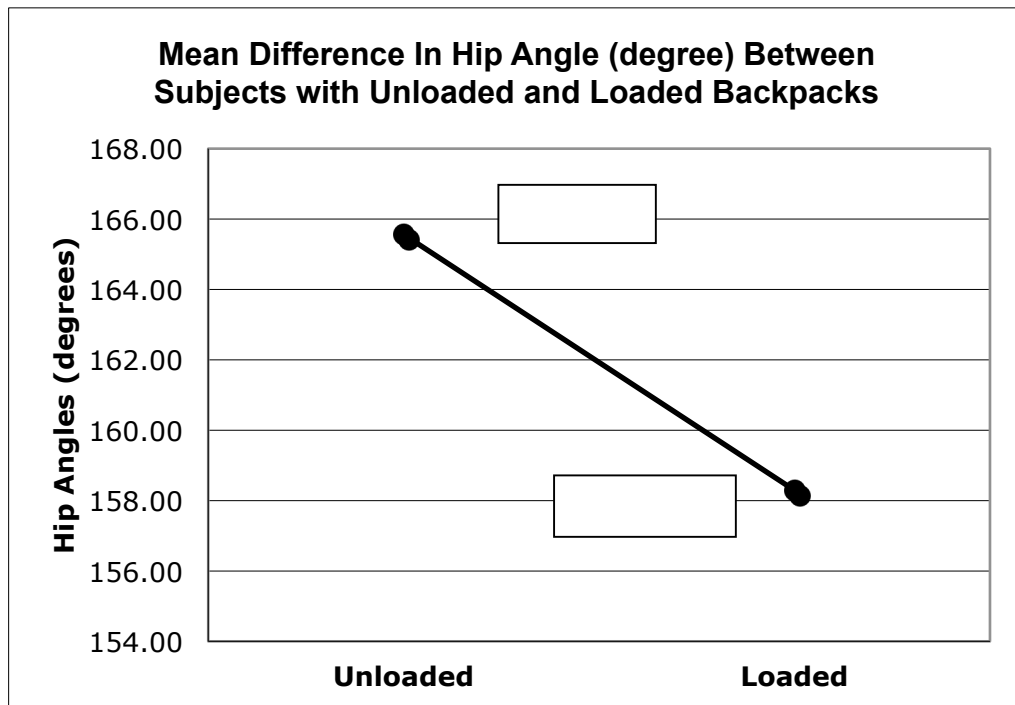


Chart 1. Mean Difference in Hip Angle

Vertical Displacement

Analysis of the vertical displacement of the COM was performed by tracking the COM trajectory during a complete gait cycle and calculating the height difference between the peaks and troughs during each trial. Mean vertical displacement for subjects COM in each unloaded trial was $8.03\text{cm} \pm .906$. In the loaded trials the mean vertical displacement was $8.23\text{cm} \pm .76$ cm.

One tailed T-test was performed ($t. \geq .099$) along with a two tailed T-test ($t \geq .198$). No significant difference was found on measures of vertical displacement between loaded and unloaded walking.

Velocity

Subjects' velocity was measured by using Dartfish software to determine how many meters the subjects' traveled per second in each trial. Average velocity of subjects in unloaded walking was 1.171 m/s $+ .109$ m/s. During walking with a posterior load, average walking velocity was 1.170 m/s $+ .088$.

Using the one tailed T-test ($t. \geq .442$), and the two tailed T-test ($t. \geq .884$) no significant difference was found between velocities of ambulation versus loaded and unloaded walking. These results indicate that velocity of subjects' ambulation was not influenced by presence of posterior load, as walking speed generally remained consistent between each trial.

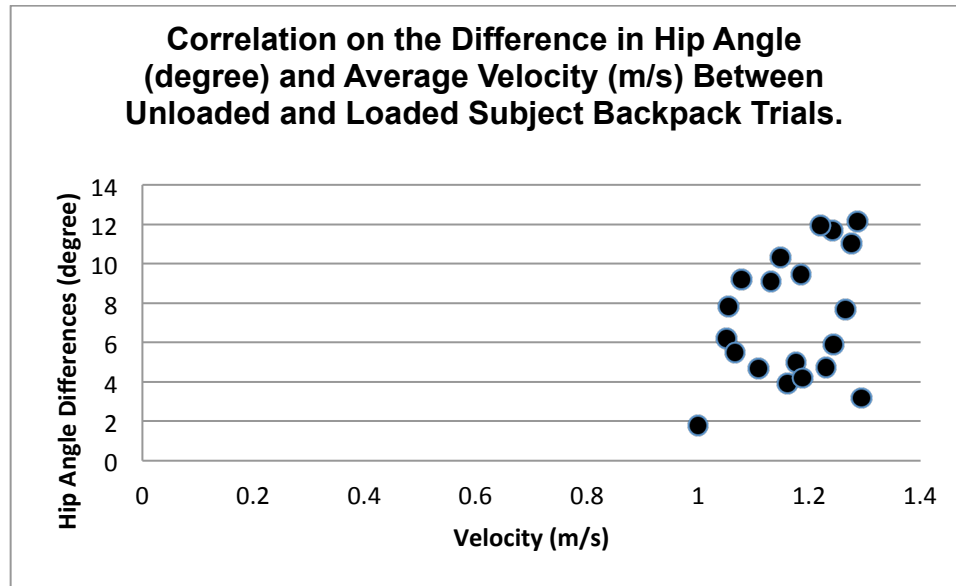


Chart 2. Difference in Hip Angle and Average Velocity between Conditions

Table 1
Means

Unloaded hip angle (degrees)	165.562
Loaded hip angle	158.292

Mean Difference	7.270 degrees
------------------------	----------------------

Unloaded Vertical Displacement (cm)	8.033
Loaded Vertical Displacement (cm)	8.225

Mean Difference	0.192 cm
------------------------	-----------------

Unloaded Velocity (m/s)	1.172
Loaded Velocity (m/s)	1.170

Mean Difference	0.002 m/s
------------------------	------------------

Table 2

One Tailed and Two Tailed T-Tests (P<.05)

Hip Angle (degrees)

One tail : $t < .01$ (significant)

Two tail : $t < .01$ (significant)

Vertical Displacement (cm)

One tail : $t. \geq 0.099$ (no sig diff between conditions)

Two tail : $t. \geq 0.198$ (no sig diff between conditions)

Velocity (m/s)

One tail : $t. \geq 0.442$ (no sig diff between conditions)

Two tail : $t. \geq 0.884$ (no sig diff between conditions)

Demographic Comparisons

Additional statistical analysis was conducted in order to deeper understand demographic consideration based on changes in COM. Pearson Correlation Coefficient was performed to determine if any correlation exists between degrees of forward flexion during loaded walking with the answers provided by the questionnaire filled out by each participant. No significant difference was found between degree of trunk flexion walking and height in centimeters (cm) of subject (F=.891), subject weight in kilograms (kg) (F=.561), weekly cardiovascular exercise frequency (F=.545) or weekly resistance exercise frequency (F=.216).

There was also no significant difference indicated between trunk flexion angle during loaded walking and velocity in m/s ($F = .304$).

Table 3

Pearson Correlation Coefficient for Angle of Trunk Flexion During Loaded Walking and Demographic Measures ($P < .05$)

Demographic Measure	P value	Significance
Weight (kg)	0.891	No
Height (cm)	0.561	No
CV PA frequency (days/wk)	0.545	No
Resistance PA Frequency (days/wk)	0.216	No
Velocity (m/s)	0.304	No

CHAPTER V

CONCLUSION

It is indicated based on these results that a backpack worn at 10% of an individuals' body weight does not seem to affect the COM compared to unloaded trials during static standing. Vertical COM also does not appear to change between loaded and unloaded trials. The angle about the COM (the forward flexion of the trunk) however, is on average decreased (moving farther from vertical) during loaded walking as compared to unloaded walking. Based on these findings, this data also indicates that angle of trunk forward flexion as a result of a posterior load wear is not correlated based on individuals weight, height, weekly exercise frequency or velocity during ambulation. These findings are consistent with other research [3] [27][17].

The results of this study can be explained by the body's ability to compensate for added loads by shifting the location of COM. In the case of backpack wear, the top half of the body flexes forward, and the COM shifts forward to allow more stabilization during static standing. In ambulation, the less displacement from peak to trough that is evident during vertical displacement of the COM, the more energy is conserved. Based on the findings of this study, it can be assumed that other aspects of gait are compensating, such as stride length, in order for the COM to remain on its energy efficient path.

Significance

The significance of the findings of forward flexion changes indicate that adults in higher education are susceptible to the same stresses on the lower back found in schoolchildren carrying 10-20% of their body weight in backpacks. Further research should be conducted on the incidence of injury in college age adults as a result of backpack stress.

Limitations

The data collection during the static standing portion of the study encountered some error. A postural stability test was selected for each trial, without specific information received from the computer of the Biodex system based on which quadrant and concentric circle the COP was located. The tracking marks of the COP were received from the printout. Data analysis was therefore performed qualitatively, with the principle investigator comparing the tracking marks from each trial. While no significant difference was found between loaded and unloaded trials based on visual inspection of COP tracking, it is recommended that in future study, data is analyzed quantitatively by receiving specific information from the computer based on percentage of time spent in specific quadrant of concentric zone.

Recommendations

It is recommended based on these results that further research is conducted on lumbosacral forces created at L4- L5 and L5-S1 joints in adults carrying 10% of body weight. Former research has indicated increased lumbosacral forces with 15%-20% of body weight carriage[3], however, adults attending 2-3 college classes a day are more likely to carry less weight than generally researched. It is therefore important to determine if lower weights contribute to lower spine and sacral stresses which may lead to lower back pain and repetitive stress injuries. Additionally, it may be useful to use a Risk Fall Assessment using the Biodex machine in further studies to determine if the posterior load of a backpack will increase the risk of falling.

Further research should also be conducted on the incidence of asymmetry and imbalance due to posterior load carriage by adults. Lee et al. investigated the effects of this muscle imbalance after it is related to low back pain. It was found that individuals suffering from low back pain generally demonstrated lower extensor muscle strength versus trunk flexor muscle strength [29]. Motmons et al. [28] and Bobet et al. have investigated the muscle activity of the body during load carriage during backpack use. Using EMG (electromyographic) activity data, it was determined that the rectus abdominal muscles had more activity than the posterior erector spinae muscles [28]. Therefore while the body is forced into this forward flexed position with load carriage, the muscles will be exposed to stretch/shortening cycles that could lead to a muscle imbalance of the lower extremity, and therefore low back pain. The imbalance is created by tight (strong) hip flexor muscles located on the anterior aspect of the body (iliopsoas, rectus femoris, and abdominal muscles) and lax (stretched) back extensor/hip extensor muscles located on the posterior aspect of the body (gluteus muscle group, erector spinae muscle group). The hip flexor muscles are shortened due to a prolonged forward flexed stance, which in turn causes the back extensor muscles to stretch and weaken as they are unable to counter balance the weight of the heavy posterior load. After short loaded periods, this muscle imbalance may be a temporary side effect that is corrected after stretching out the anterior muscles and correcting posture after posterior load removal. However, as backpack carriage becomes more frequent, the time muscles are spent in the stretch/shortened cycle also increases, which in turn could lead to a pathological posture even after posterior load is removed.

APPENDIX

Appendix A

Consent Form for the Student Body Backpack Study The Department of Health and Human Performance

The principle investigator is Emma Stephens. She can be contacted at 210-846-9775, or by email at ES1302@txstate.edu.

INTRODUCTION AND PURPOSE OF STUDY

You have been asked to participate in a research study to assess the effect that backpack wear places on the body during standing and walking. The full purpose of this study will be explained after your participation.

You will be evaluated in the Biomechanics lab in the Jowers building room B130. The following form includes more details regarding the research if you have any questions or concerns about the study please ask before you decide to participate.

PROCEDURES

Each subject will be instructed to wear athletic clothing including a t-shirt, tight fitting shorts (i.e. biker shorts, spandex), and tennis shoes. Workout clothing is necessary for locating specific areas on the body and attaching reflective markers for body movement analysis. The following are the procedures for the study which will take about 30 minutes to complete:

1. First subjects will fill out a brief, 7 question confidential questionnaire which include questions about history of lower body injury, age, height, weight, sex and physical activity level. Subjects will then be reviewed on the procedures.
2. Next, subjects will be briefed on how to perform the next aspect on the study by the principle investigator.
3. Subjects will be asked to stand on the Biodex Balance System with arms by their sides on two feet (platform is stable). Balance will then be assessed first while subject is not wearing a backpack, then while subject is wearing a standard size, standard weight backpack.
4. Next, reflective tape will be placed on subjects' greater trochanter on their dominant side by the principle investigator. The subject will walk for two minutes without a backpack in order to warm up.
5. The principle investigator will explain the next process. The subjects will then be asked to walk at an average walking speed of 1.5 m/s for 15 meters without the backpack.

6. A slow motion camera will only record the last 5 meters of the walk, mapping the trajectory of the reflective tape on the greater trochanter.
7. After subject completes participation in study, the purpose of the study will be disclosed.

BENEFITS TO PARTICIPANTS

Participants will be briefed on the purpose of the study after participation. Hopefully, research from this study will benefit the medical and educational community. Also, the results from this investigation will help you learn about

- Problems that can be created by wearing a backpack
- Changes your body goes through when wearing a backpack
- Changes in body balance without a backpack and while wearing a backpack.

POTENTIAL RISKS AND DISCOMFORTS

Subjects will be informed of potential risks and discomforts before participating in the study. The physical demands placed on the subject for this study are not strenuous, and the risk of injury is minimal. The warm up period before the walking section of the study will also prevent injury by allowing the muscles to adapt. The principle investigator will be monitoring all aspects of the subjects' to further decrease the chance of injury.

If an emergency occurs during testing the subjects will be instructed to exit the building immediately. If it is a medical emergency then emergency services will be contacted. The primary investigator is Professional Rescuer Certified and will assist with all emergency situations until EMS arrives on the scene.

CONFIDENTIALITY

All participants will be assigned a number in order to differentiate between subjects and results without disclosing name and other identifying information. Name and telephone number will be required for the following form. All recorded materials will be kept on file for two years and faces will be blurred. Consent forms will not be shared for future research. In the event that consent form material is needed for research further purposes then the subjects will be contacted for additional written consent for release of their information. All data gathered from research will be kept securely at the principle investigators home office for two years after completion of the study.

PARTICIPATION

Participation in the study is completely voluntary. You may withdraw from the study at any time. If data has already been collected and you wish your information to be omitted, please contact the principle investigator. You will still be entitled to awards owed. Your results from the study will then be either destroyed or returned depending on your wishes. Results of the study will be provided if requested to the principle investigator. If you have any other questions regarding the research, research participants' rights, and/or research-

related injuries to participants please contact the IRB chair, Dr. Jon Lasser, (512) 245-3413, lasser@txstate.edu or to Ms. Becky Northcut, Compliance Specialist, (512) 245 2102.

AUTHORIZATION

The Department of Health and Human Performance is committed to the practice of protection for human subjects participating in research and related activities. The consent form has been provided in order to determine your participation in the study. Complete study can be accessed on the Texas State University library website under the ecommons@txstate tab author name Emma Stephens.

“I have read the above statement and have been fully advised of the procedures to be used in this project. I have been given sufficient opportunity to ask any questions I had concerning the procedures and know that I am free to ask questions as they may arise. I likewise understand that I can withdraw from the study at any time without being subjected to reproach.”

Contact Emma Stephens (210)846-9775 or ES1302@txstate.edu with any additional question or concerns.

Participant Name Printed (18 years or older)

Phone #

Signature

Principle Investigator Signature

Appendix B

Backpack Study Questionnaire

Please answer the following questions as honestly as possible. Name and information will be confidential.

1) What is your sex (circle one)?

- a. Male b. Female

2) What is your age?

_____ Years old

3) How tall are you?

_____ Ft _____ in.

4) How much do you weigh?

_____ Pounds

5) On average, how many times a **week** do you participate in moderate to vigorous cardiopulmonary exercise for at least 30 continuous minutes?

Do not include weight/ resistance training or weight lifting.

- a. 0
- b. 1-2
- c. 3-4
- d. 5-7
- e. More than 7 times per week.

6) On average, how many times a **week** do you participate in weight/resistance training or weight lifting for at least 20 minutes?

- a. 0
- b. 1-2
- c. 3-4
- d. 5-7
- e. More than 7 times per week

7) In the last two years have you had **ANY** lower extremity injury?

Circle: Yes No

Appendix C

Subjects 3 Trial Means of Hip Angle For Unloaded and Loaded Conditions

Subject #	Unloaded Mean	Loaded Mean
1	161.833	157.900
2	159.533	147.833
3	161.333	149.367
4	161.733	155.533
5	155.433	149.567
6	166.567	161.900
7	178.000	165.867
8	166.233	158.400
9	169.633	167.833
10	163.633	160.433
11	173.100	162.100
12	164.600	159.900
13	164.900	155.433
14	172.333	166.833
15	168.467	159.367
16	165.300	157.633
17	176.433	171.467
18	166.933	157.733
19	166.133	155.833
20	150.833	144.900
Total mean	165.648	158.292
SD	6.536	6.875

Appendix D

Subjects 3 Trial Means of Hip Vertical Displacement in Unloaded and Loaded

Conditions

Subject #	Unloaded Mean (cm)	Loaded Mean (cm)
1	7.643	7.113
2	8.913	8.527
3	8.463	9.573
4	8.030	8.307
5	7.793	8.253
6	9.730	9.280
7	9.487	9.030
8	6.827	8.470
9	7.557	8.287
10	8.663	8.103
11	9.227	8.803
12	8.960	8.610
13	7.827	7.900
14	7.530	8.627
15	8.037	8.503
16	7.737	8.163
17	7.677	8.153
18	7.250	6.997
19	6.367	7.070
20	6.940	6.733
Total mean	8.033	8.225
SD	0.907	0.757

Appendix E

Subjects 3 Trial Means of Velocity in Unloaded and Loaded Conditions

Subject #	Unloaded Mean (m/s)	Loaded Mean (m/s)
1	1.207	1.161
2	1.297	1.242
3	1.158	1.219
4	1.092	1.050
5	1.232	1.244
6	1.122	1.108
7	1.309	1.286
8	1.036	1.055
9	0.977	1.000
10	1.384	1.294
11	1.241	1.276
12	1.301	1.229
13	1.109	1.184
14	1.021	1.066
15	1.126	1.131
16	1.249	1.265
17	1.074	1.176
18	1.083	1.078
19	1.240	1.148
20	1.176	1.187
Total mean	1.172	1.170
SD	0.110	0.088

Appendix F

Subject Demographic Measures

Subject #	Ht. (cm)	Wt.(kg)	Velocity (m/s)	Hip Angle Difference	CV PA level(days/wk)	Resistance PA level (days/wk)	sex
1	165.1	65	1.16	3.93	4	2	F
2	180.34	71.36	1.24	11.7	2	0	F
3	160.02	62.73	1.22	11.97	2	0	F
4	179.07	71.36	1.05	6.2	4	4	M
5	182.88	85.45	1.24	5.87	2	4	M
6	186.69	73.18	1.11	4.67	2	2	M
7	161.29	59.09	1.29	12.13	4	2	F
8	165.1	75	1.06	7.83	4	4	F
9	175.26	72.73	1	1.8	2	4	M
10	157.48	70.45	1.29	3.2	2	2	F
11	168.1	86.36	1.28	11	2	2	F
12	190.5	91.36	1.23	4.7	8	4	M
13	172.72	69.09	1.18	9.47	4	4	F
14	167.64	67.27	1.07	5.5	7	4	F
15	167.64	100	1.13	9.1	2	2	F
16	170.18	68.18	1.27	7.67	7	2	M
17	162.56	54.54	1.18	4.97	4	2	F
18	170.18	68.18	1.08	9.2	4	2	F
19	162.56	58.18	1.15	10.3	2	4	F
20	152.4	72.72	1.19	4.2	2	0	F
Mean	169.89	72.11	1.17	7.27	3.5	2.5	
SD	10.01	11.28	0.09	3.19	1.91	1.43	

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