INFLUENCE OF CARRYING BACKPACKS ON THE GAIT CYCLE & POSTURE OF UNIVERSITY STUDENTS

PHY 317 - Introduction to Human Biomechanics

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MOTIVATION

WE NOTICED THAT OUR FRIENDS ON CAMPUS WALKED AROUND WITH THEIR BACKPACKS IN DIFFERENT WAYS SO WE DECIDED TO SPRINKLE IN SOME BIOMECHANICS

SINGLE STRAP

DOUBLE STRAP

BAG IN HAND

SURVEY

WE BEGAN OUR ANALYSIS BY CONDUCTING A PRELIMINARY SURVEY OF STUDENTS AT LUMS TO UNDERSTAND HOW THEY WEAR THEIR BACKPACKS AND HOW IT AFFECTS THEIR HEALTH

Survey

Age *

Your answer

Gender *

- ○ Male
- ○ Female
- ○ Prefer not to say

How do you wear your backpack? *

- ○ Two-strap on the shoulder
- ○ One-strap on the shoulder
- ○ In hand, briefcase-style
- ○ Other:

How would you describe the weight of your bag? *

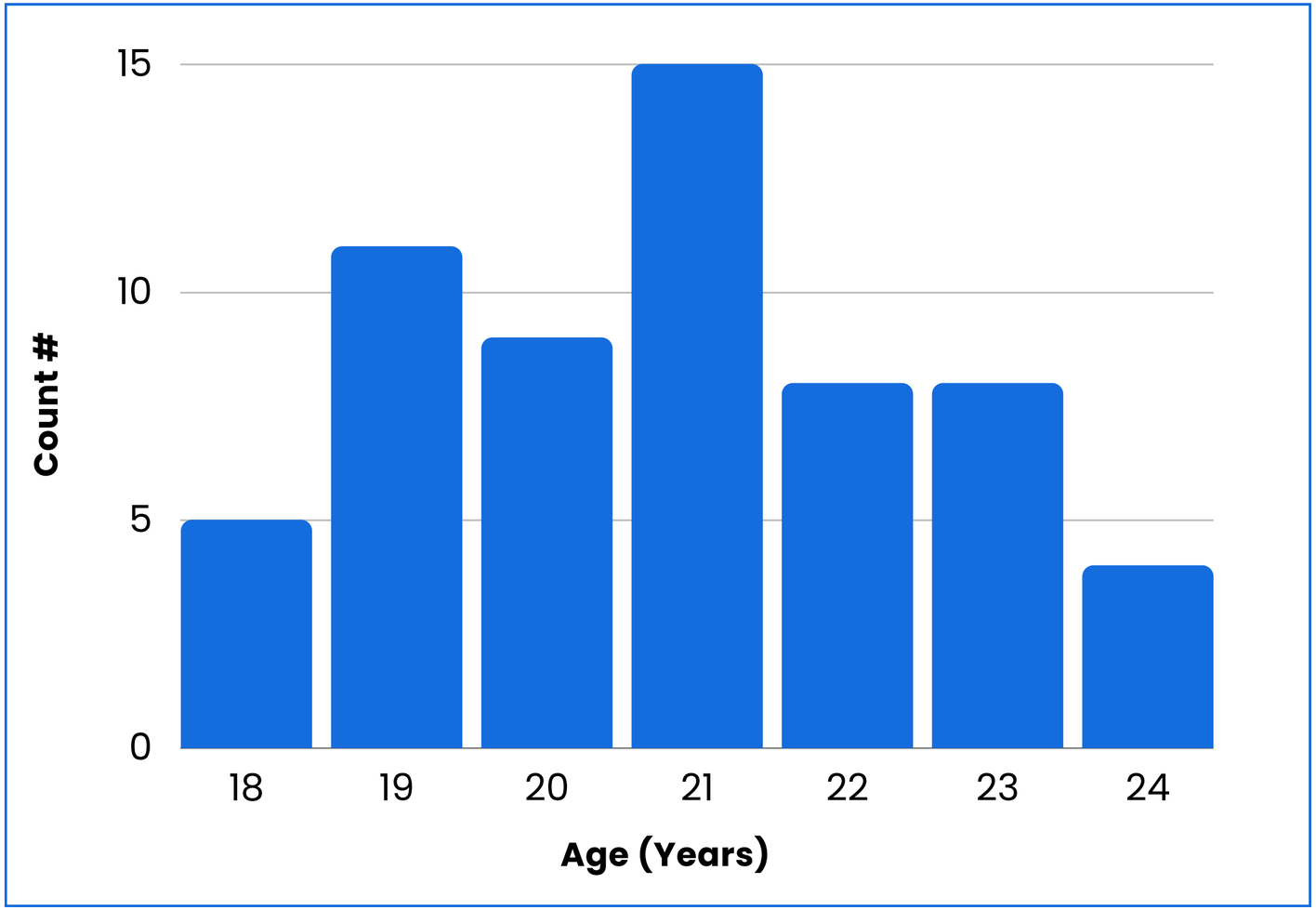
- ○ Heavy
- ○ Medium
- ○ Light

Mark any adverse physical symptoms you experience due to wearing your backpack.

- ☐ Shoulder pain
- ☐ Neck pain
- ☐ Back pain
- ☐ Muscle soreness
- ☐ Numbness
- ☐ Weakness in the arms and/or legs
- ☐ Bad posture
- ☐ Other:

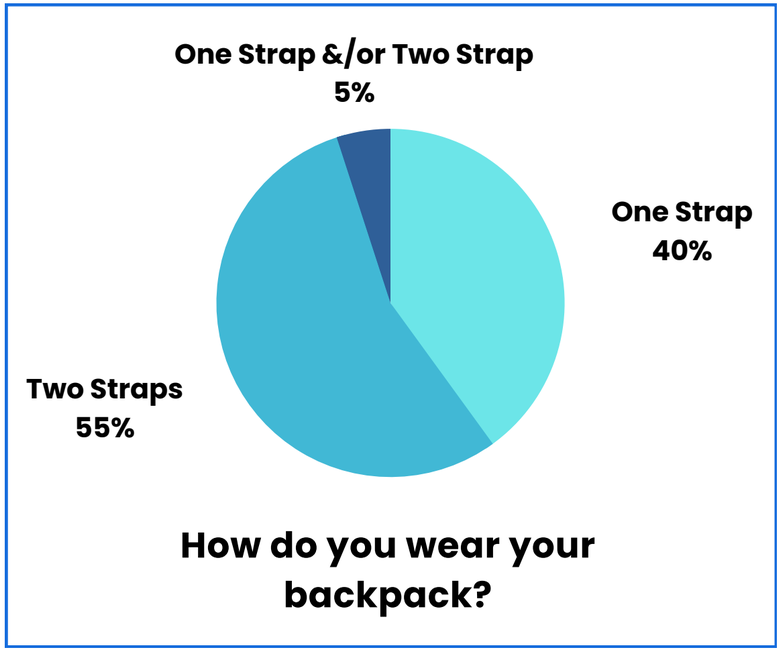
SURVEY RESULTS

A brief overview



60 Survey Respondents

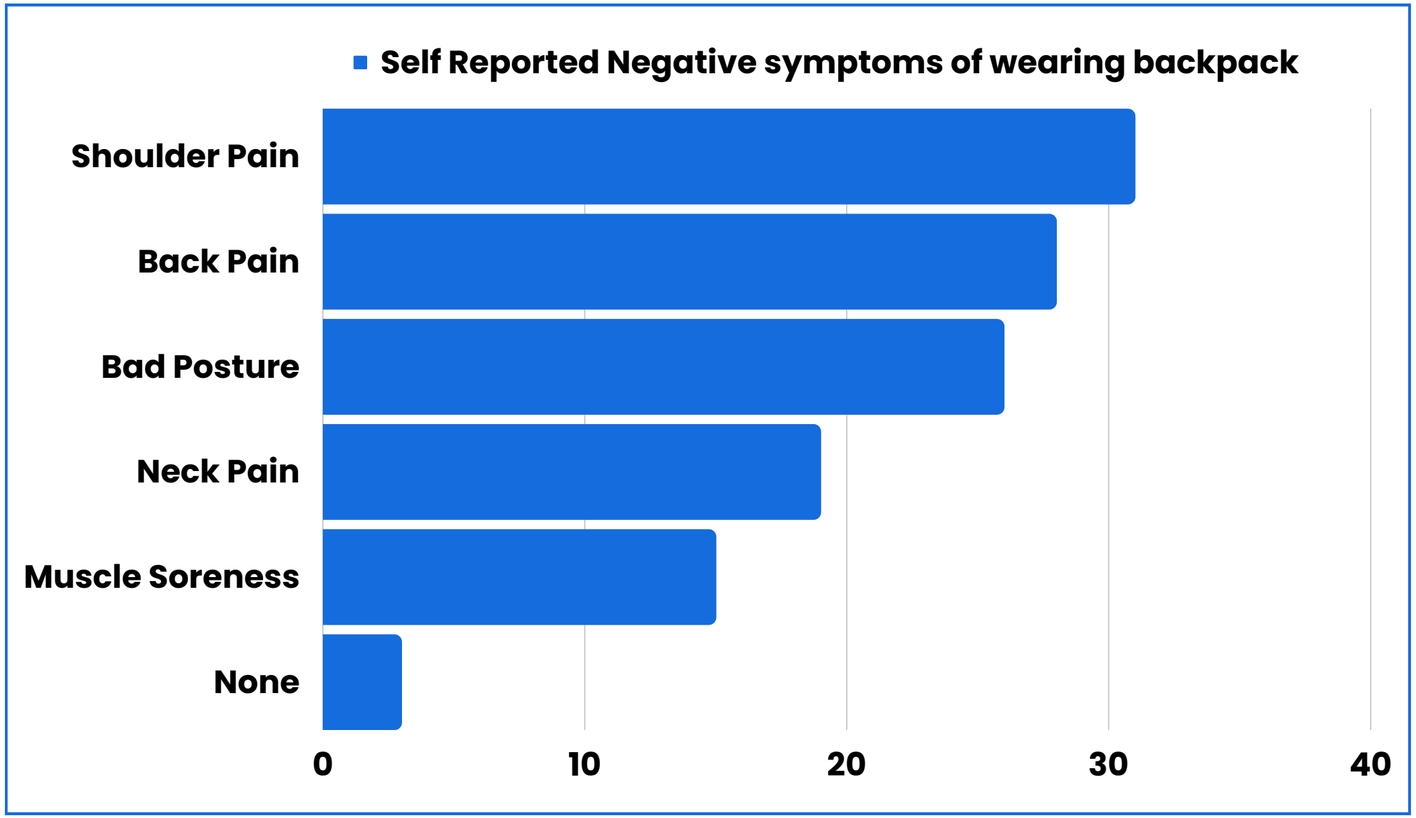
- 32 Males
- 28 Females

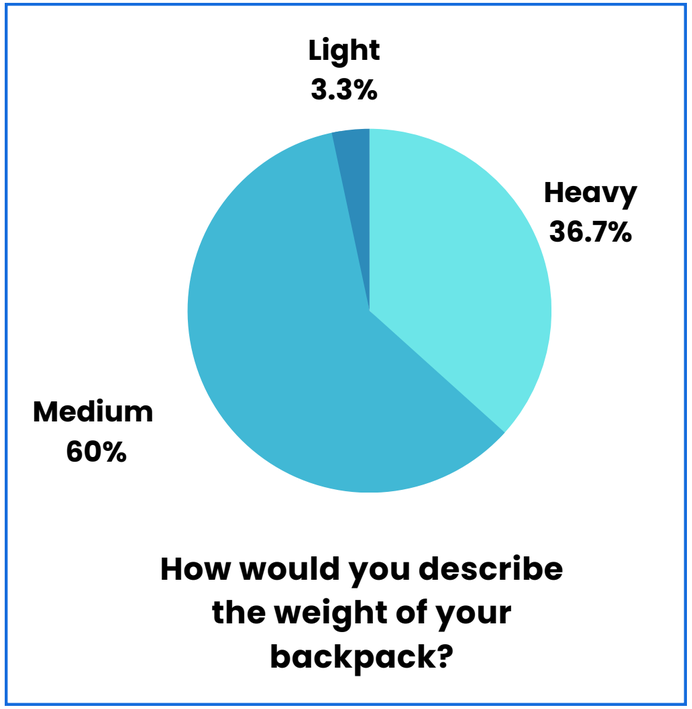


SURVEY RESULTS

Continued

- 96.7% respondents stated that their backpacks weight was **'medium' and 'heavy'**
- 95% respondants stated **negative symptoms** of wear a backpack on their health





MOTIVATION IGNITED

AFTER LEARNING ABOUT THE WIDESPREAD HEALTH IMPACT OF WEARING A BACKPACK ON OUR FELLOWS, WE DECIDED TO COMBINE OUR KNOWLEDGE OF BIOMECHANICS TO DEVELOP A DEEPER UNDERSTANDING OF HOW WEARING A BACKPACK IMPACTS THEIR POSTURE AND GAIT

EXPERIMENT OVERVIEW

WE DECIDED TO FILM PARTICIPANTS FROM DIFFERENT ANGLES AS THEY WALKED WITH/WITHOUT WEARING BACKPACK WITH DIFFERENT STRAP POSITIONS AND CONDUCTED AN INDEPTH VIDEO ANALYSIS

PARTICIPANT INFORMATION

WE RECRUITED 10 PARTICIPANTS

- 6 MALES & 4 FEMALES
- AVERAGE MASS = 63.35 KG'S
- AVERAGE HEIGHT = 5'5
- AVERAGE AGE = 21.2 YRS

Participant #	Gender	Age	Height	Mass (kgs)	Have you had an injury that may have affected your ability to walk over the past 3 months?
Participant 1	Female	21	5'4	55	No
Participant 2	Female	22	5'0	54	No
Participant 3	Female	21	5'3	71	No
Participant 4	Female	23	5'4	48	No
Participant 5	Male	21	5'11	68	No
Participant 6	Male	22	5'6	69	No
Participant 7	Male	18	5'9	80	No
Participant 8	Male	20	6'2	70	No
Participant 9	Male	21	5'4	55	No
Participant 10	Male	23	5'7	63	*"No, not in the past month but had an existing childhood injury that introduced shoulder imbalance in walking posture"*

EXPERIMENTAL SETUP

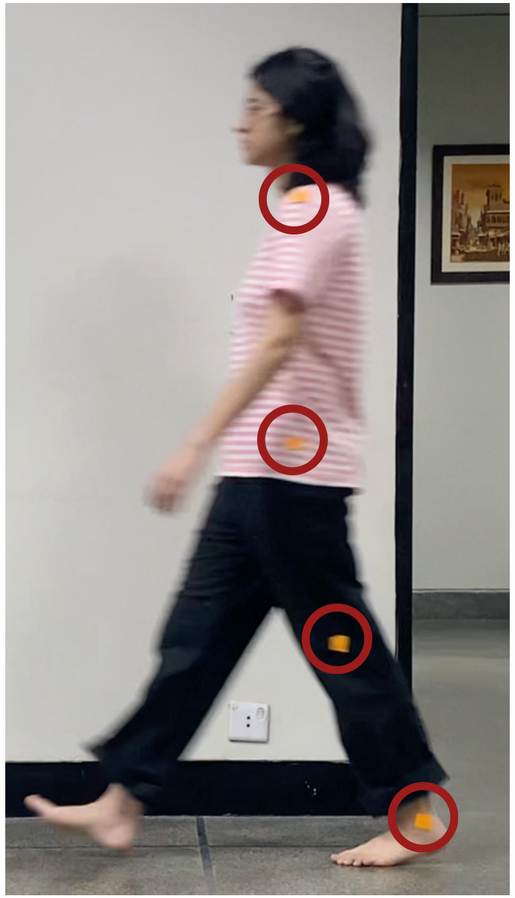
LOCATION & CAMERA PLACEMENT

- ALL VIDEOS WERE SHOT ON A IPHONE 11 PRO CAMERA, PLACED IN THE SAME LOCATION
- PARTICIPANTS WALKED BAREFOOT
- MARKERS MADE OF COLOR PAPER WERE PLACED ON PARTICIPANT'S JOINTS
- VIDEOS TAKEN FROM SIDE VIEW AND FRONT VIEW

EXPERIMENTAL SETUP

MARKER PLACEMENT

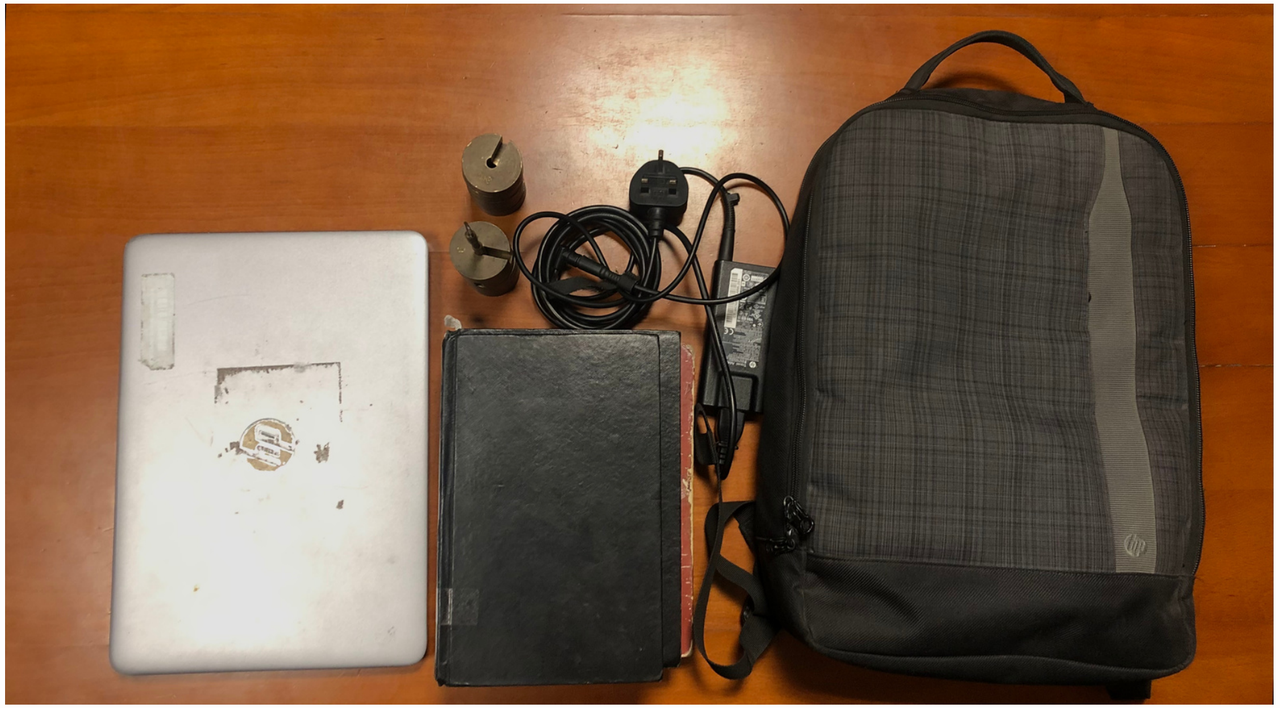
- 6 MARKERS FOR THE FRONT VIDEO ANALYSIS
- 4 MARKERS FOR THE SIDE VIDEO ANALYSIS
- MEASUREMENTS: 4 ANGLES, STRIDE TIME, AND STRIDE LENGTH



EXPERIMENTAL SETUP

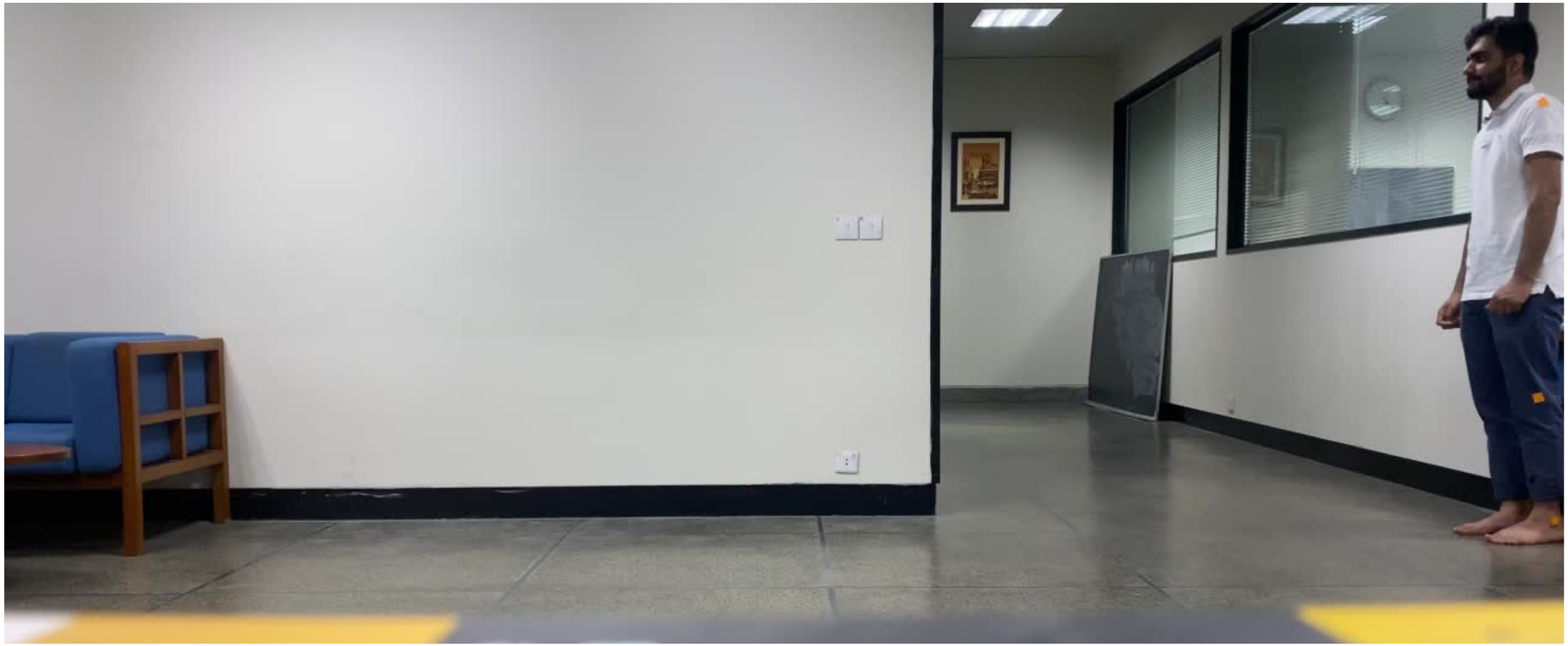
BACKPACK WEIGHT AND CONTENTS

- ALL PARTICIPANTS WORE THE SAME BACKPACK WEIGHING 7.3 KGS
- THE BACKPACK CONTAINED CONTENTS SIMILAR TO WHAT TYPICAL STUDENTS WOULD CARRY ON A DAILY BASIS
- SOME ADDITIONAL WEIGHTS WERE USED TO BRING THE BACKPACK UP TO WEIGHT



SAMPLE VIDEOS

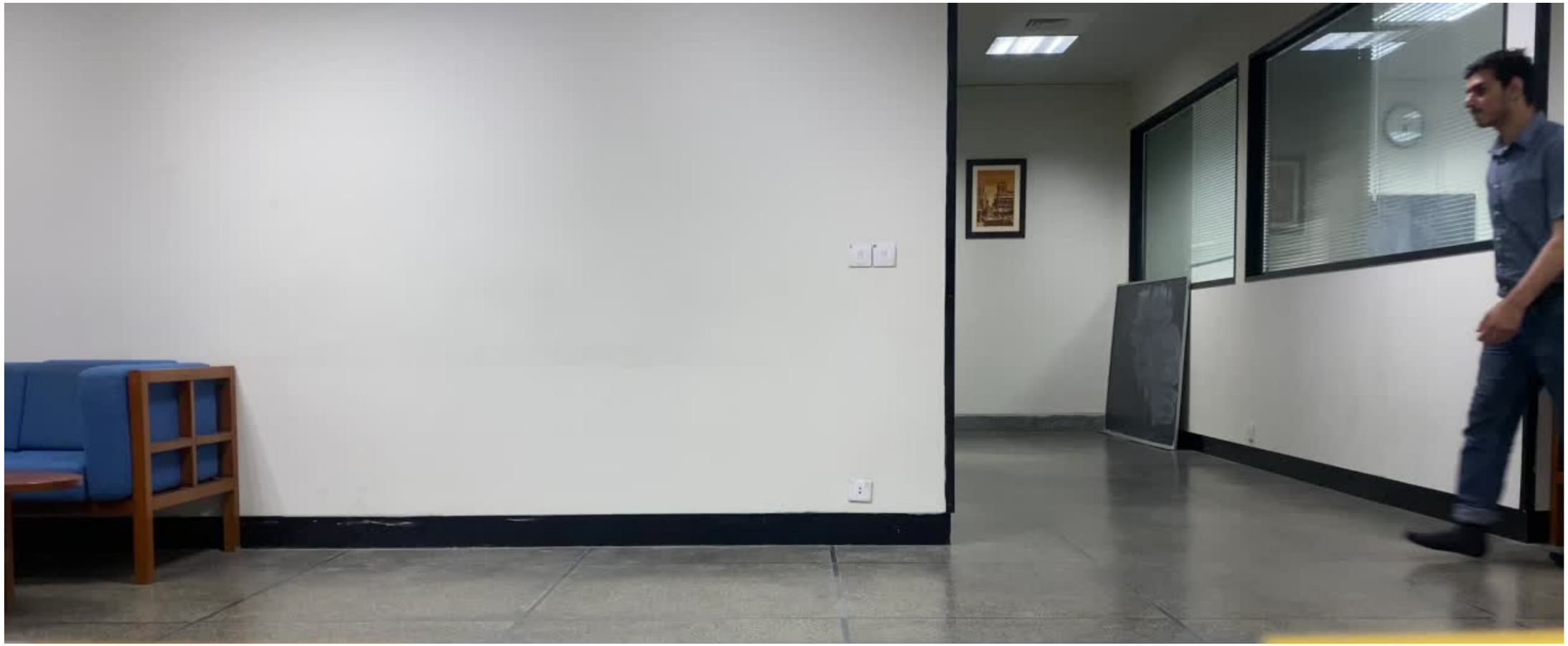
THESE ARE SOME OF THE VIDEOS WE MADE USING OUR EXPERIMENTAL SETUP



Side - No Backpack

SAMPLE VIDEOS

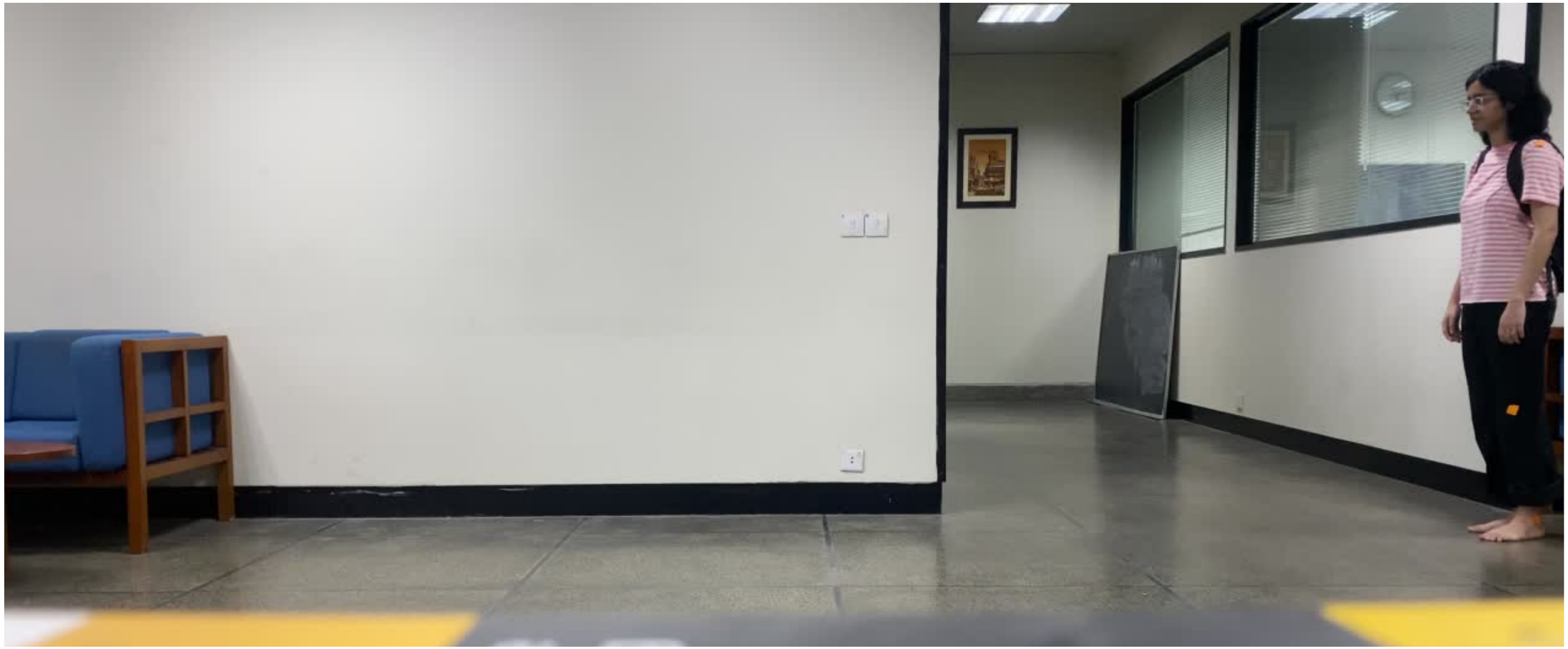
CONTINUED



Side - Single Strap

SAMPLE VIDEOS

CONTINUED



Side - Double Strap

SAMPLE VIDEOS

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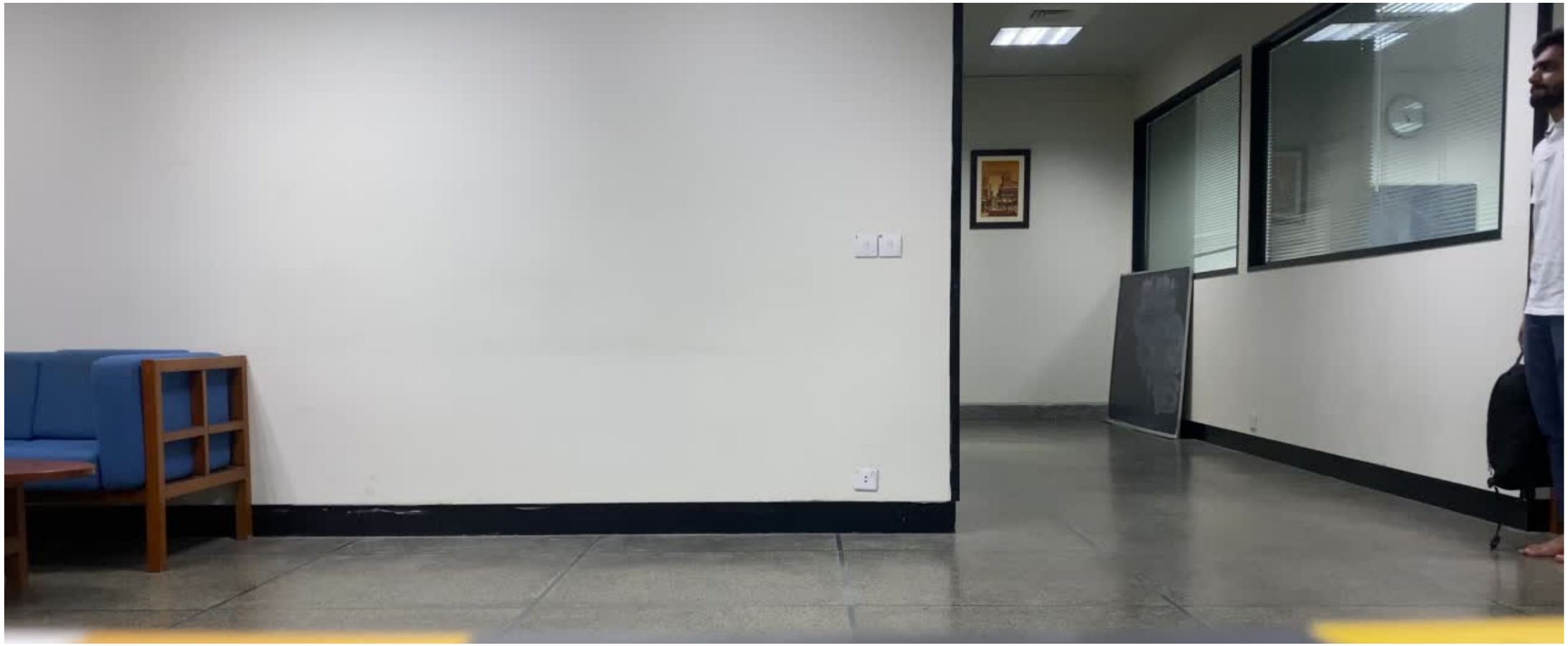


Side - Bag in Hand

SAMPLE VIDEOS

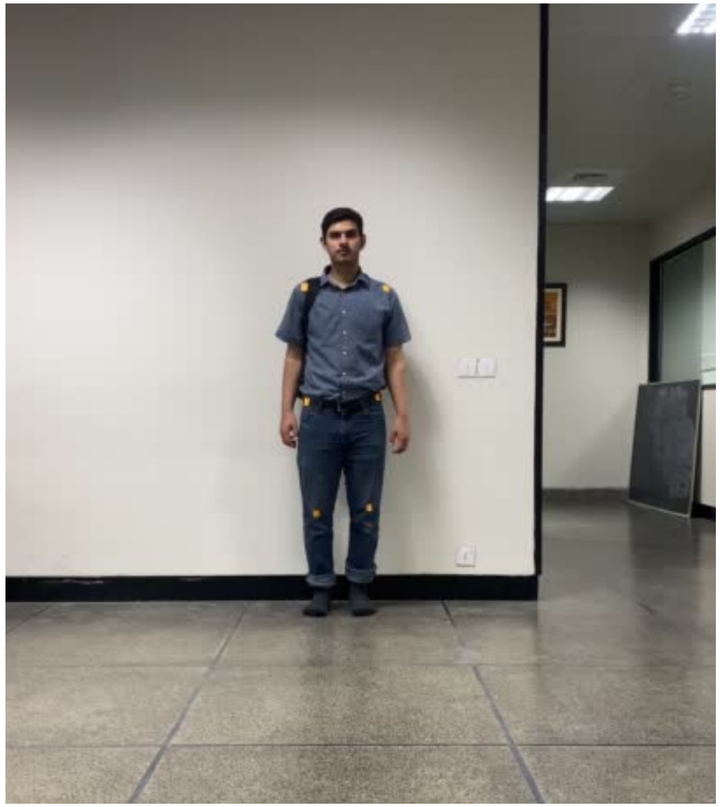
CONTINUED

Front - No Backpack

Front - Backpack in hand

SAMPLE VIDEOS

CONTINUED

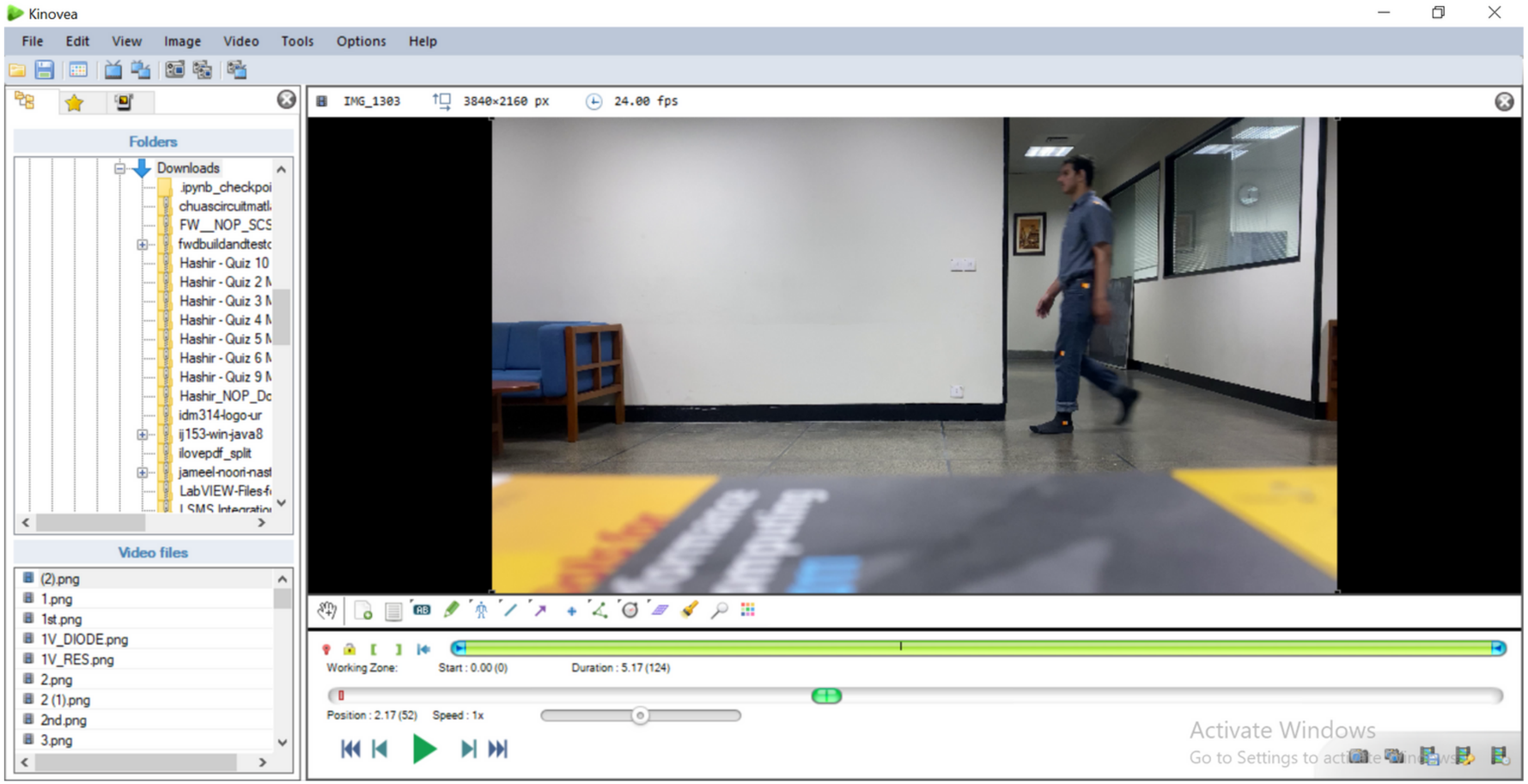


Front - Single Strap

Front - Double Strap

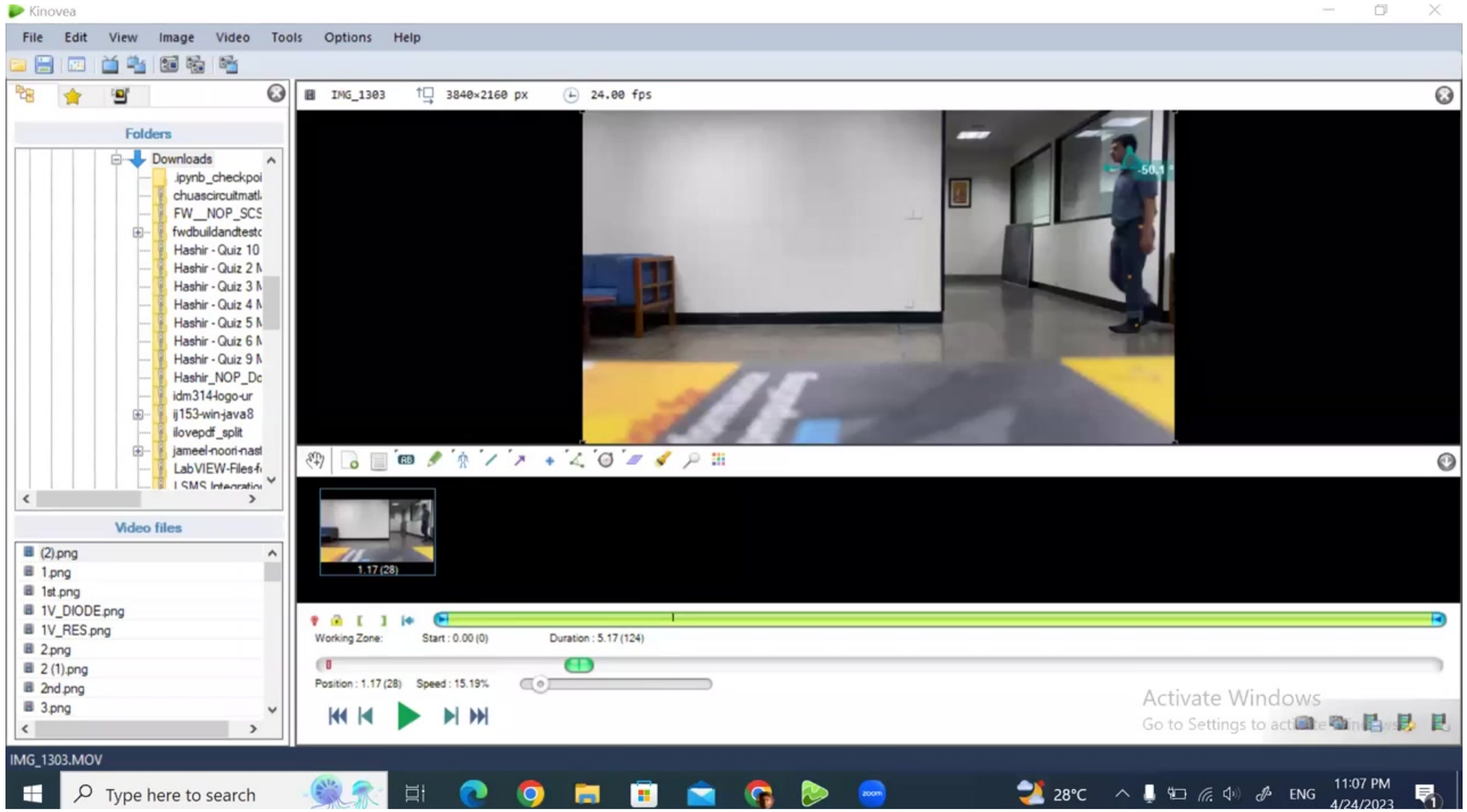
VIDEO ANALYSIS USING KINOVEA

KINOVEA IS A 2-D MOTION TRACKING SOFTWARE THAT IS FREE TO USE THAT PROVIDES MULTIPLE FEATURES INCLUDE THE ABILITY TO TRACK MARKERS, RECORD CHANGING ANGLES, LINEAR AND ANGULAR KINEMATICS MEASUREMENTS



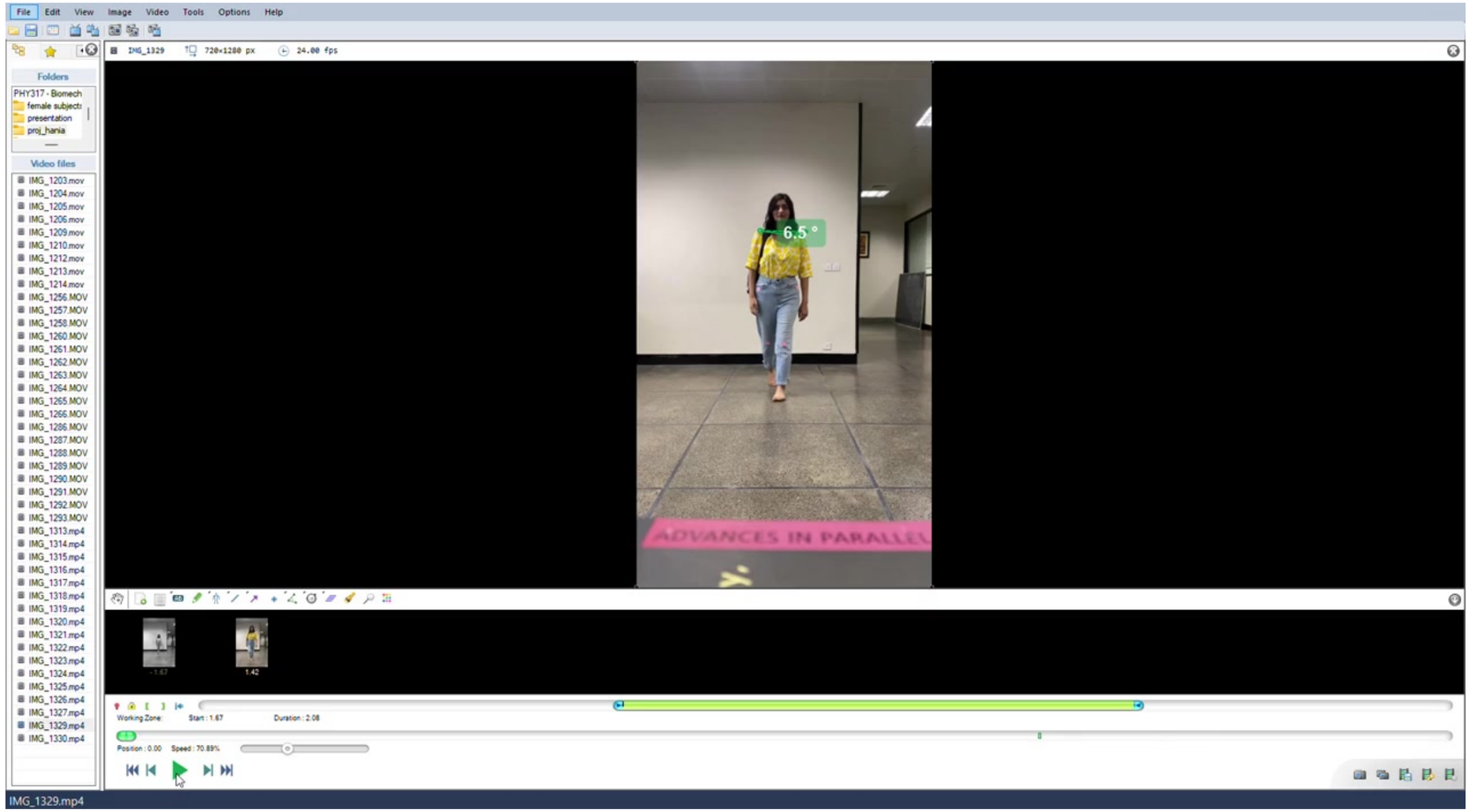
SAMPLE KINOVEA ANGLE TRACKING

WE USED KINOVEA TO TRACK ANGLES THROUGHOUT THE VIDEO



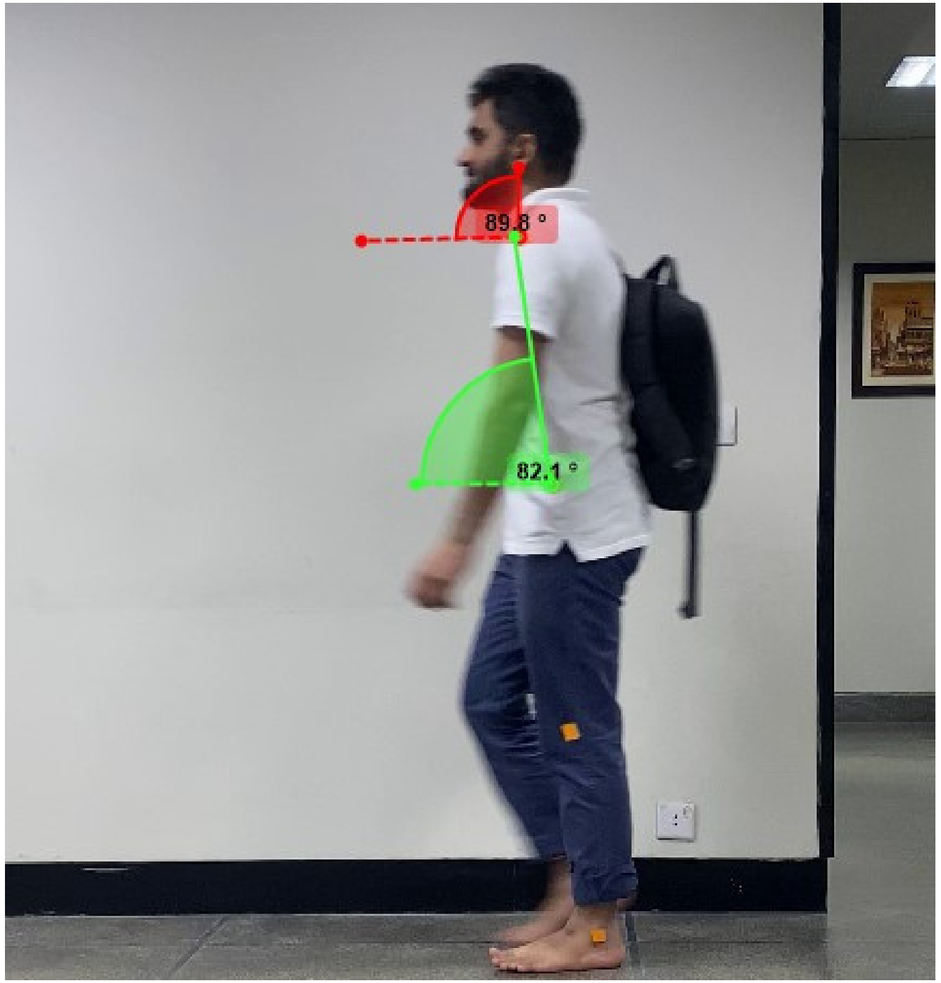
SAMPLE KINOVEA ANGLE TRACKING

CONTINUED



SPINAL ANGLE AND HEAD ANGLE

THE SIDE-ON ANGLE WAS USED TO CALCULATE THE SPINAL AND HEAD ANGLES WITH THE HORIZONTAL AS SHOWN.

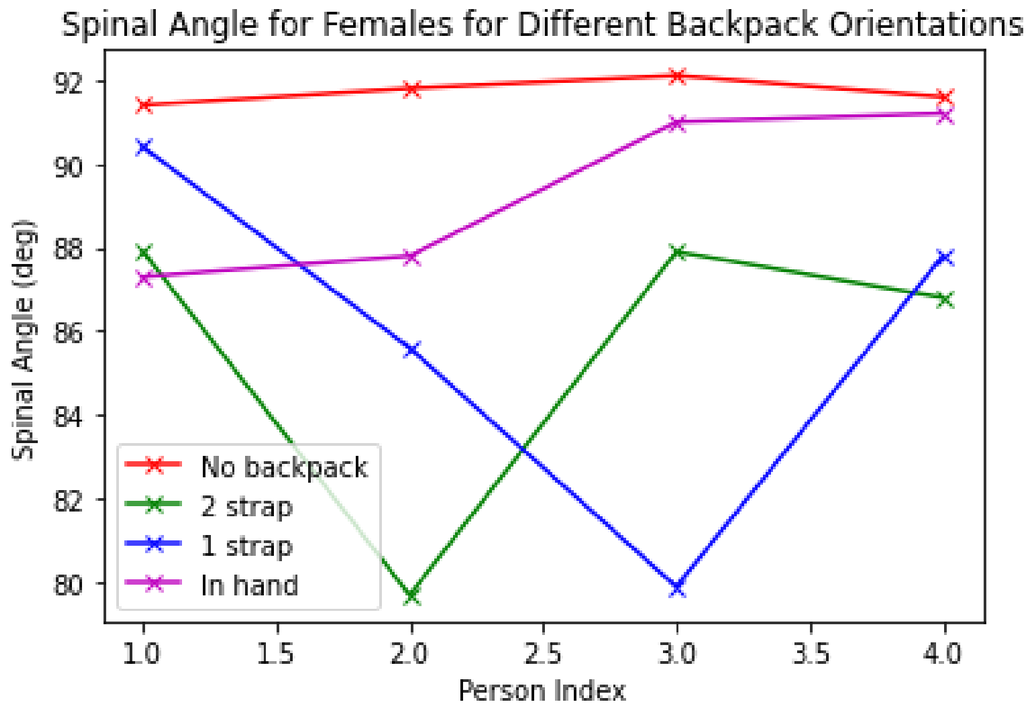


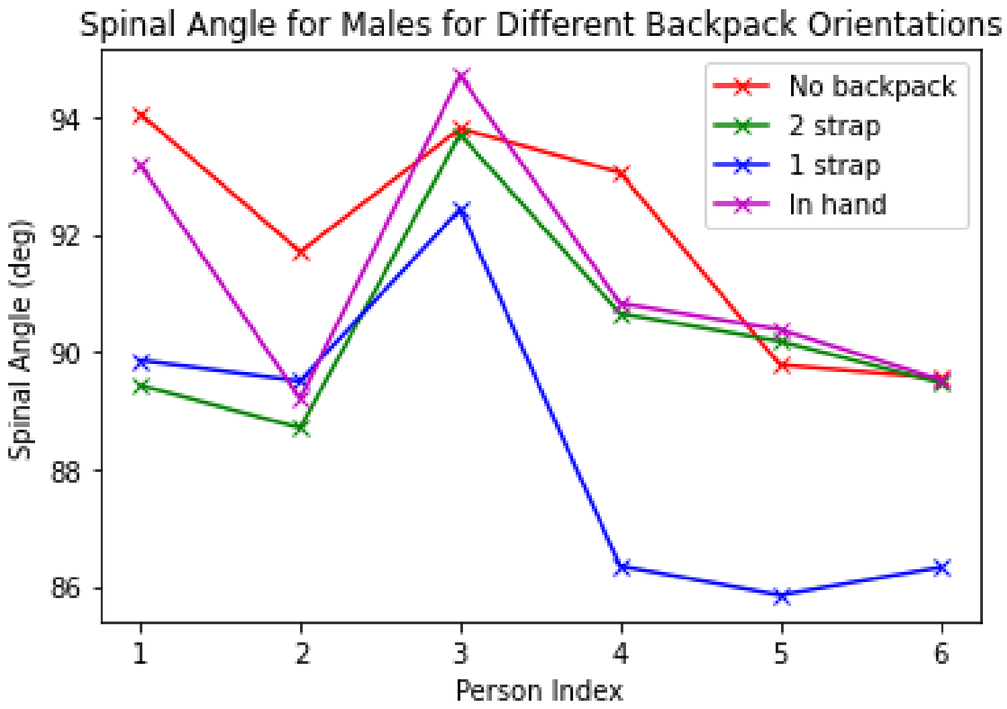
SHOULDER ELEVATION AND TRUNK ANGLE

THE FRONT-ON ANGLE WAS USED TO CALCULATE THE SHOULDER ELEVATION AND TRUNK ANGLES WITH THE HORIZONTAL AS SHOWN.

SPINAL ANGLE FOR EACH PARTICIPANT

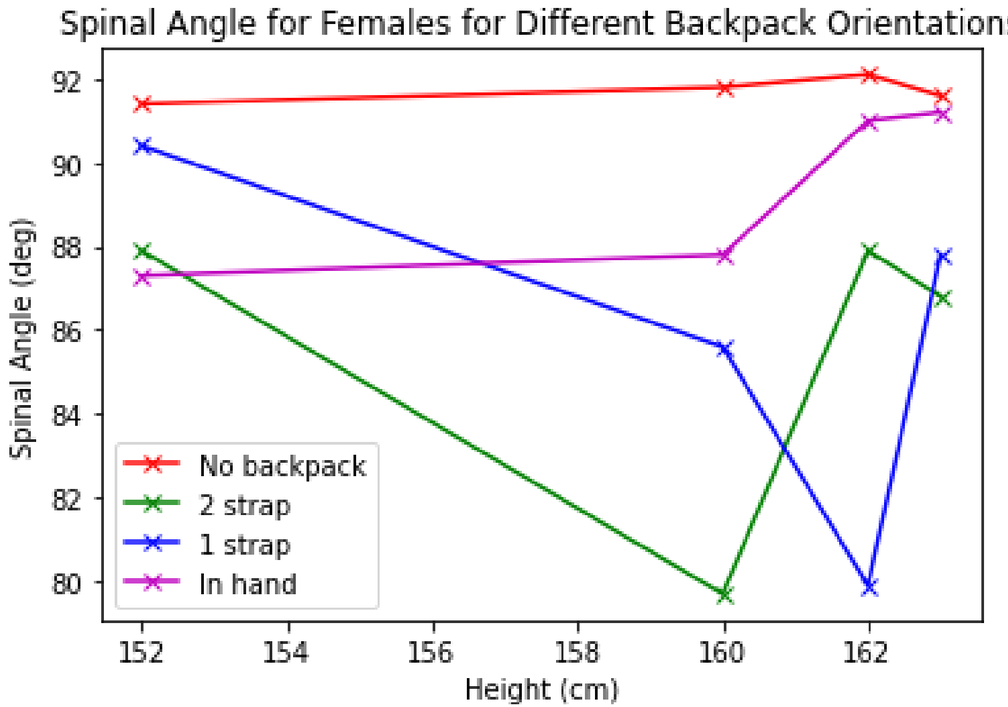
A CLEAR TREND IS THE REDUCTION IN SPINAL ANGLE WHEN GOING FROM NO BACKPACK TO A SINGLE STRAP BACKPACK

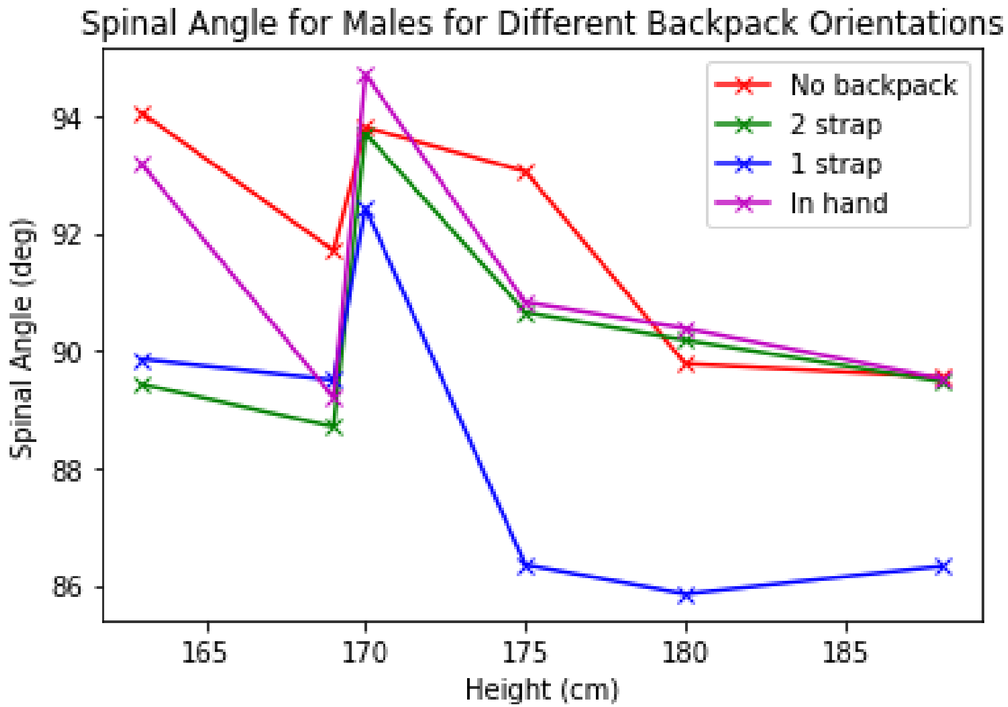




SPINAL ANGLE VS HEIGHT

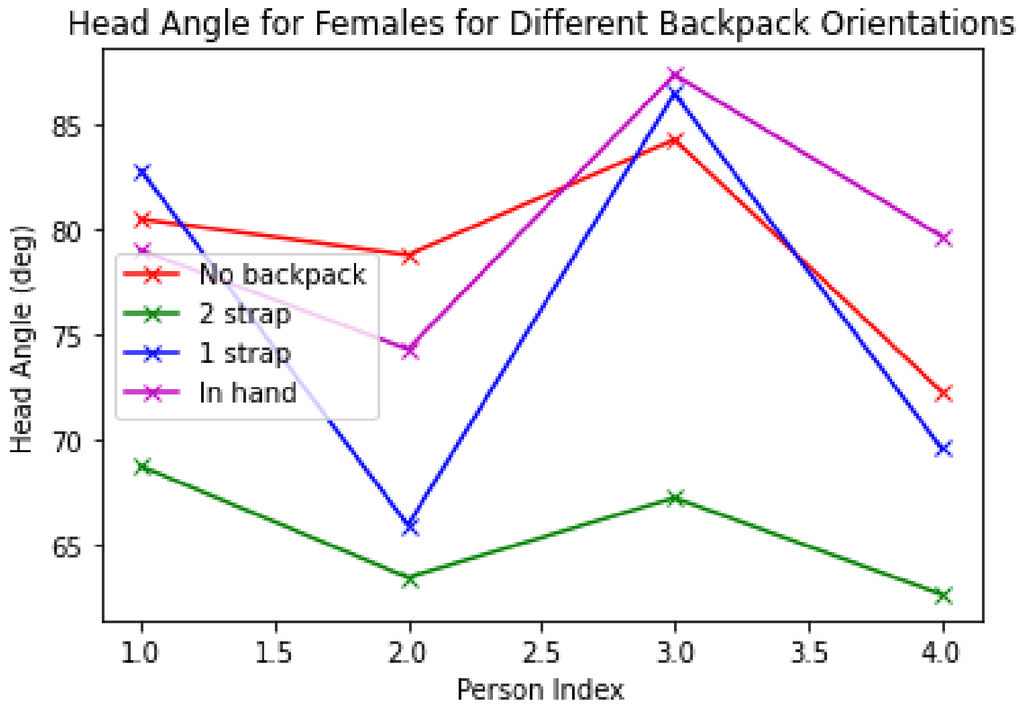
THERE IS NO CLEAR TREND IN THE EFFECT OF HEIGHT ON SPINAL ANGLE (ESPECIALLY IN FEMALES)

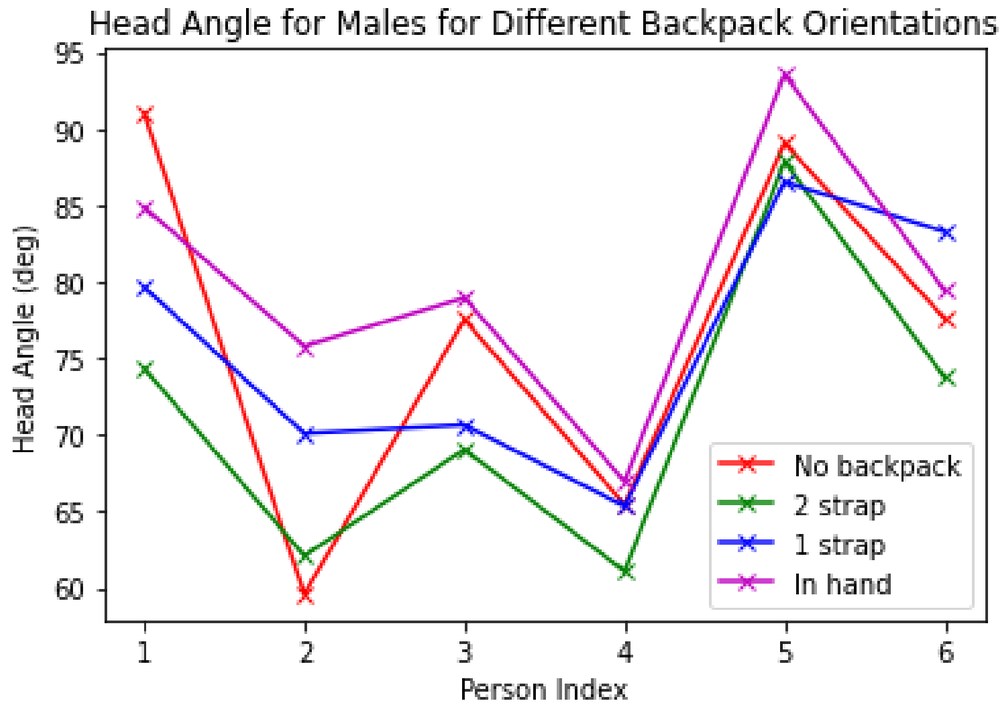




HEAD ANGLE FOR EACH PARTICIPANT

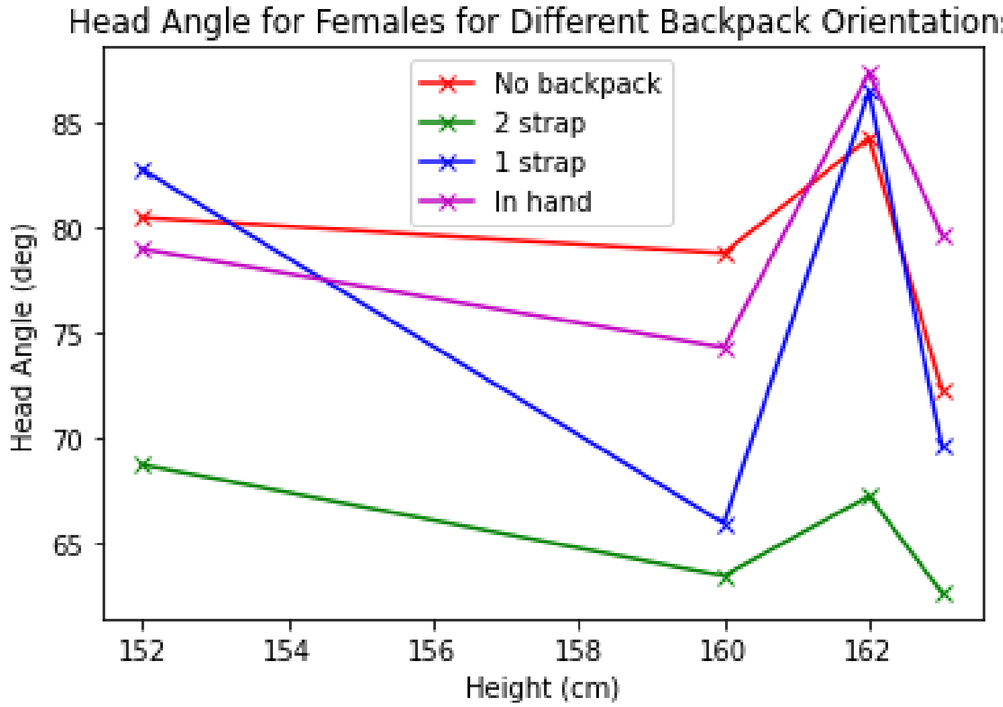
THE HEAD ANGLE DECREASES IN GOING FROM NO BACKPACK TO DOUBLE STRAP BACKPACK ALTHOUGH THE CHANGE IS NOT THAT CLEAR

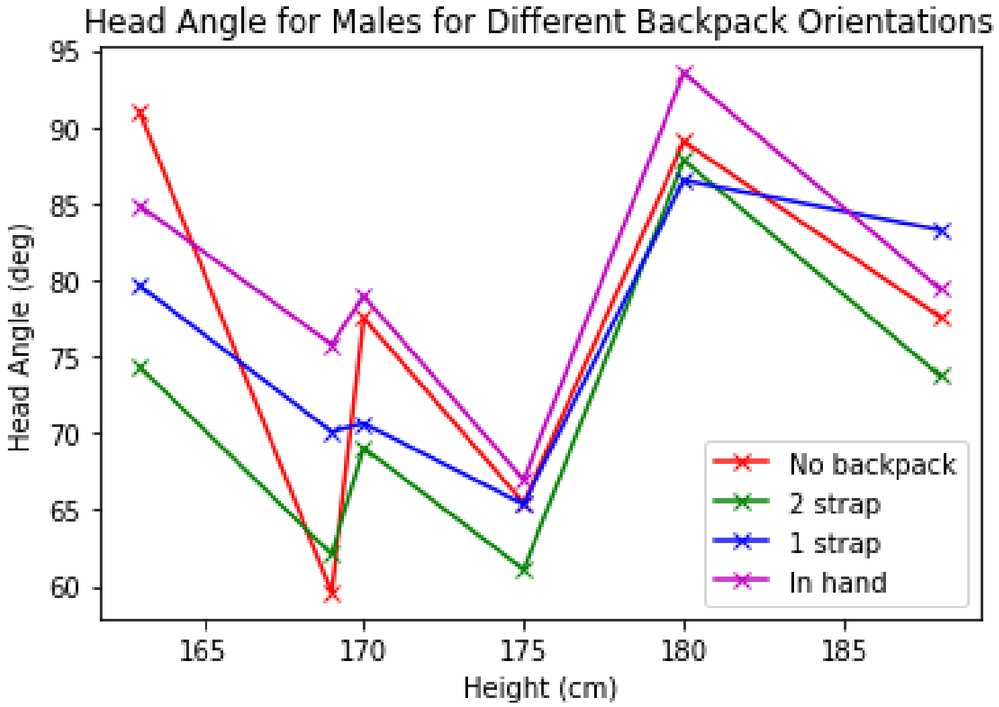




HEAD ANGLE VS HEIGHT

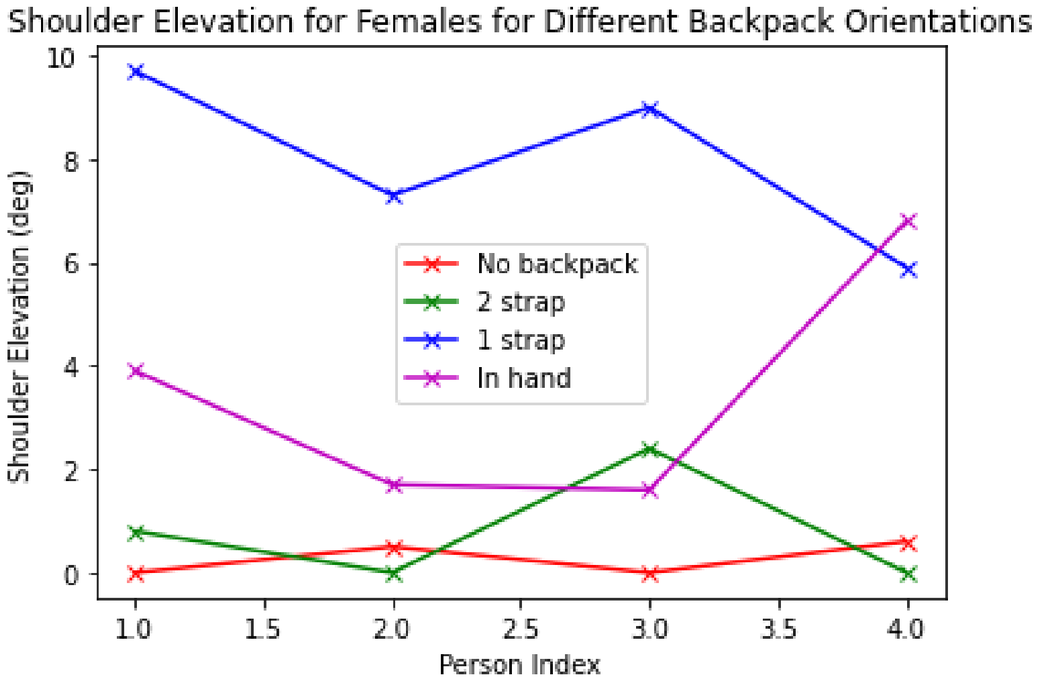
THERE IS NO CLEAR TREND IN HEIGHT DIFFERENCES ON HEAD ANGLE

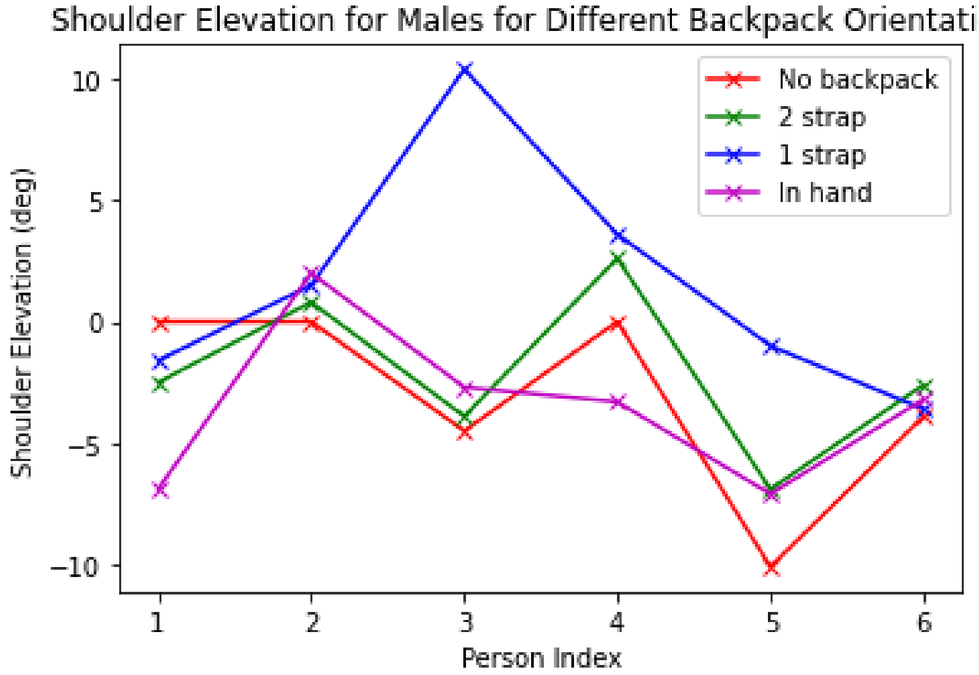




SHOULDER ELEVATION FOR EACH PARTICIPANT

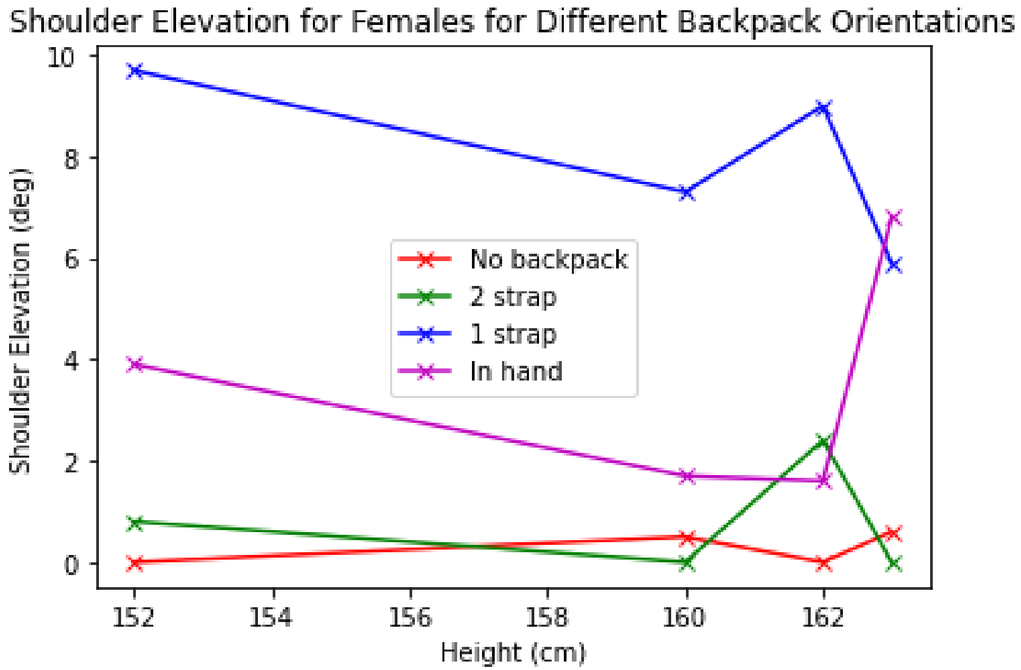
THERE IS A CONSIDERABLE DROP IN ONE SHOULDER COMPARED TO THE OTHER WHEN WEARING THE BACKPACK SINGLE STRAP. OBSERVE, IN PARTICULAR MALE NO. 5

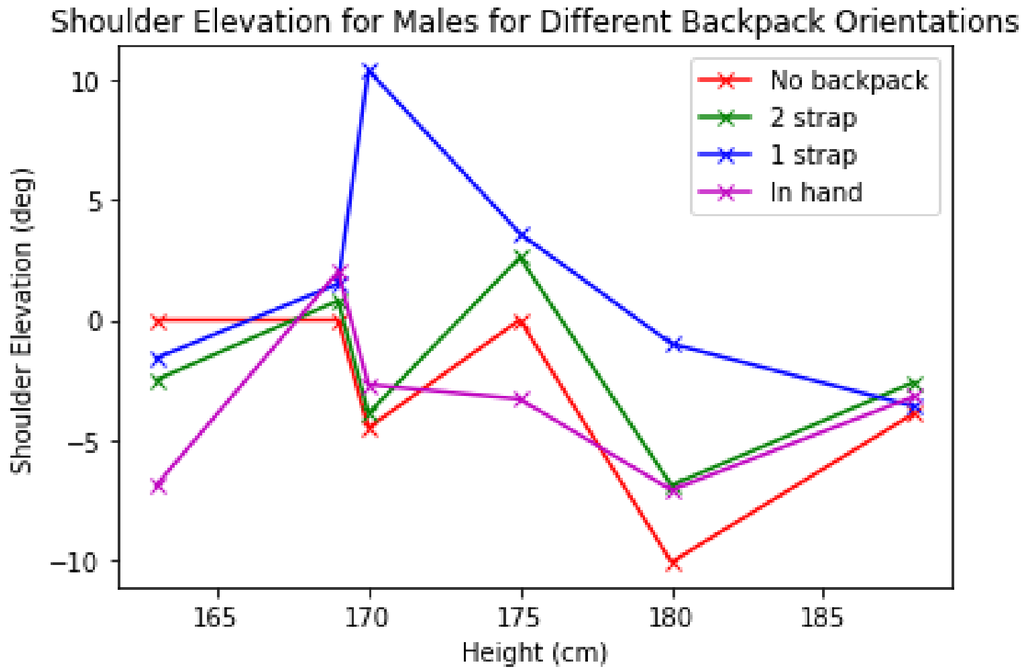




SHOULDER ELEVATION VS HEIGHT

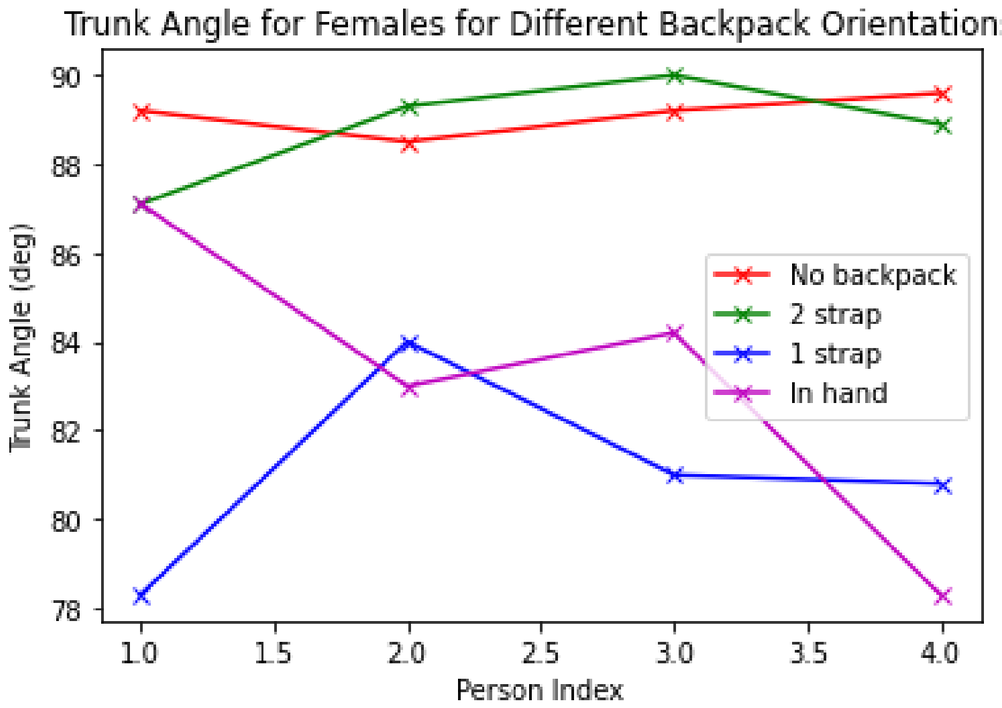
AGAIN, NO CLEAR TREND IN SHOULDER ELEVATION AND HEIGHT

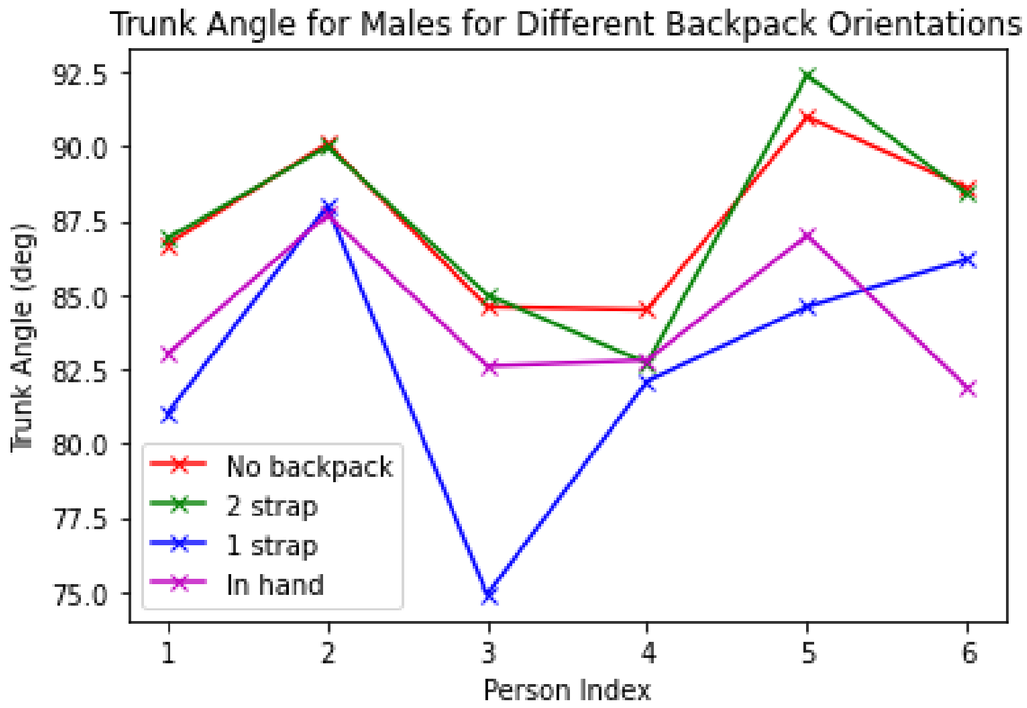




TRUNK ANGLE FOR EACH PARTICIPANT

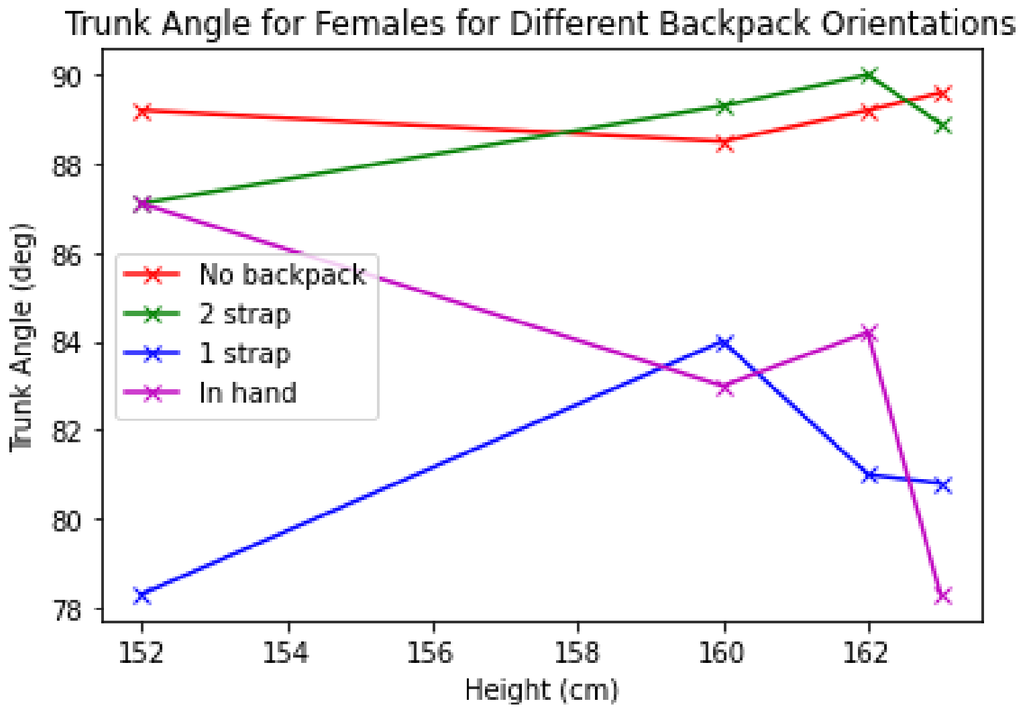
THERE IS NOT MUCH DIFFERENCE BETWEEN TRUNK ANGLES FOR DOUBLE STRAP AND NO BACKPACK. HOWEVER, THE OTHER STYLES DECREASE TRUNK ANGLE

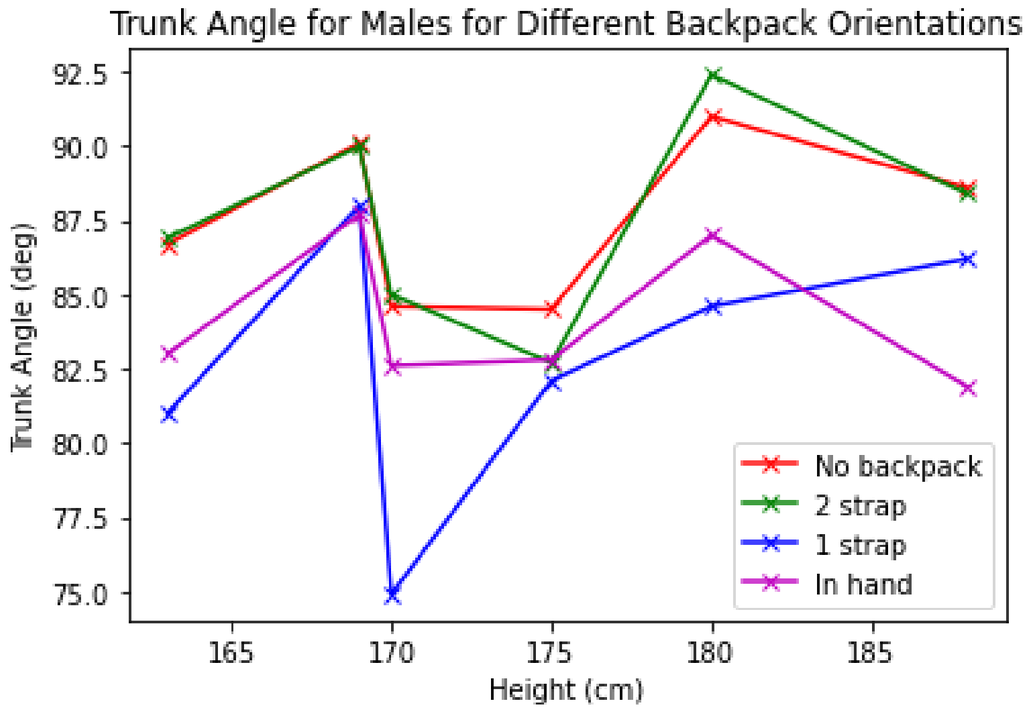




TRUNK ANGLE VS HEIGHT

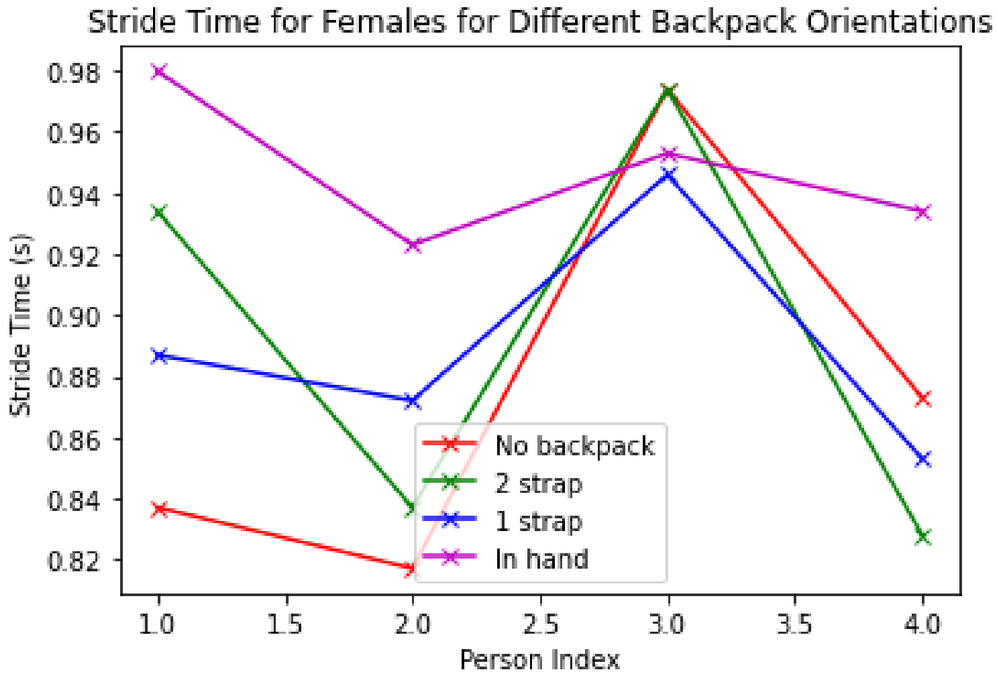
THERE APPEARS TO BE NO EFFECT OF HEIGHT ON THE TRUNK ANGLE REGARDLESS OF BACKPACK-WEARING STYLE

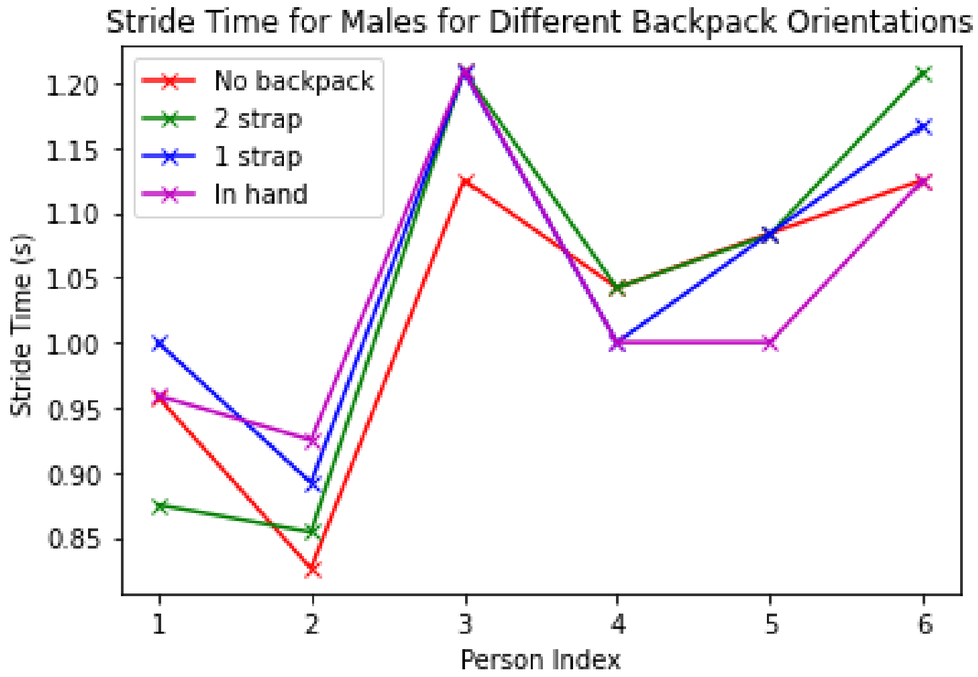




STRIDE TIME FOR EACH PARTICIPANT

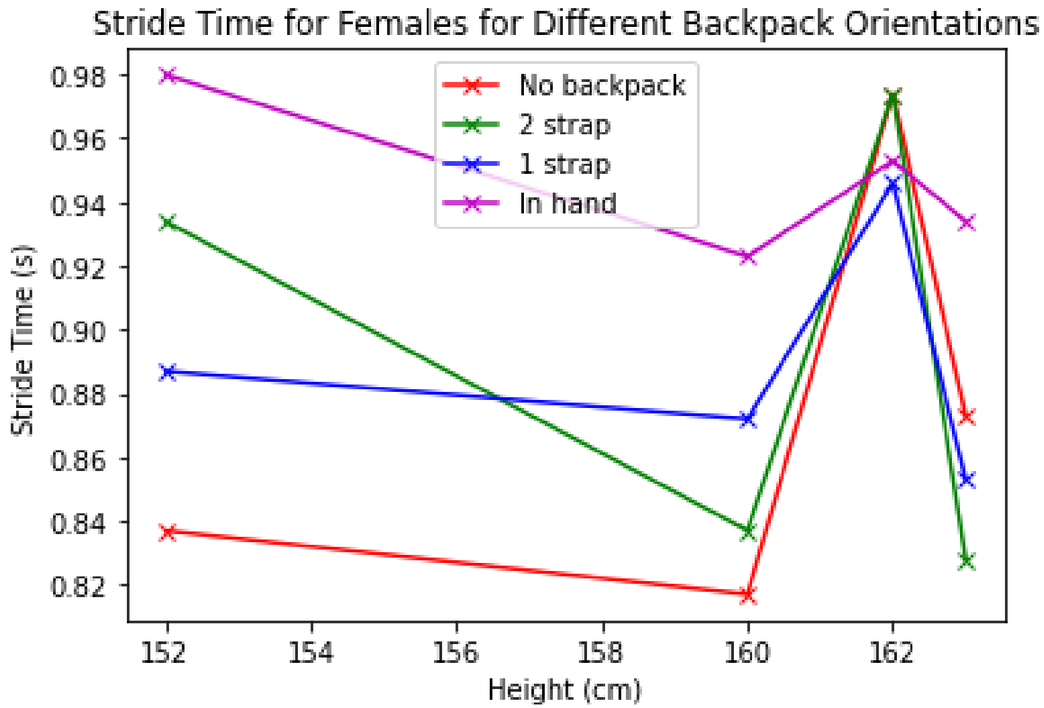
THE STRIDE TIME IS THE TIME TAKEN BETWEEN IPSILATERAL HEEL STRIKES. NO SIGNIFICANT CHANGE IN STRIDE TIMES DUE TO BACKPACK STYLE FOR MOST PEOPLE

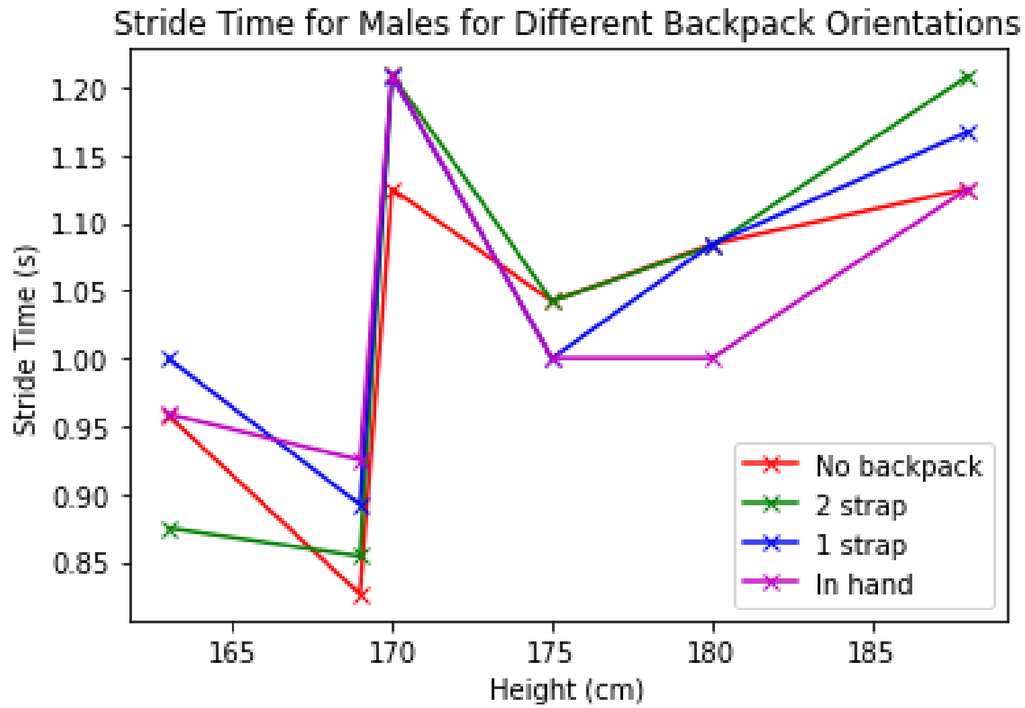




STRIDE TIME VS HEIGHT

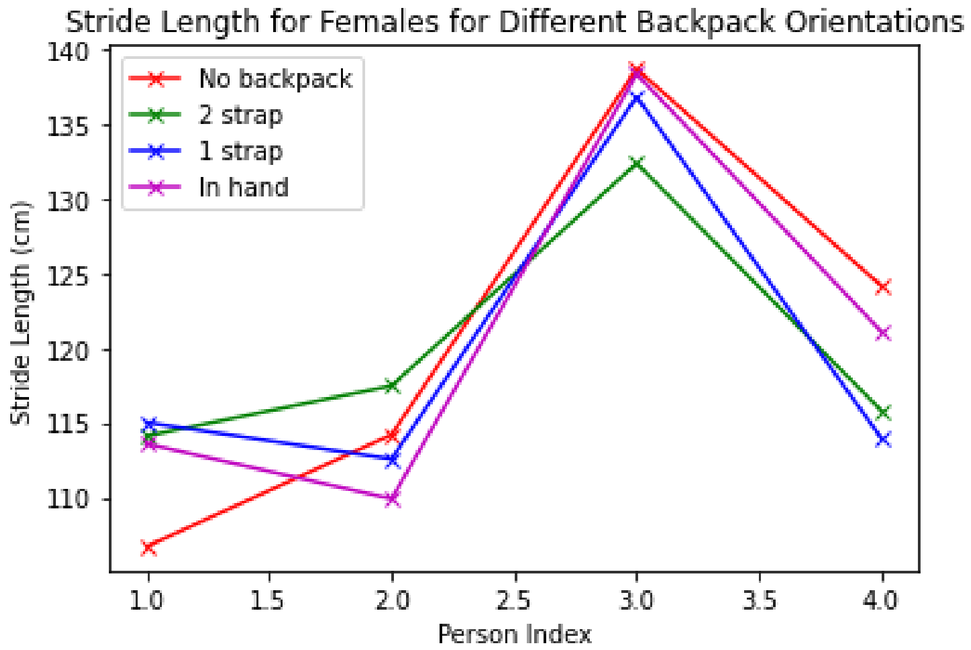
FOR MALES, STRIDE TIME APPEARS TO INCREASE WITH THE HEIGHT OF THE PERSON

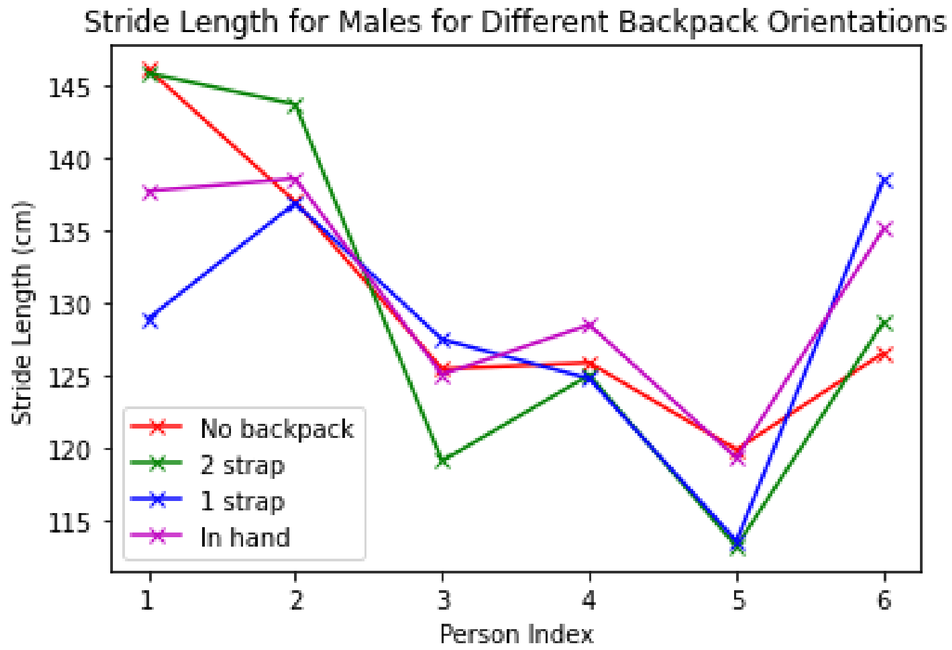




STRIDE LENGTH FOR EACH PARTICIPANT

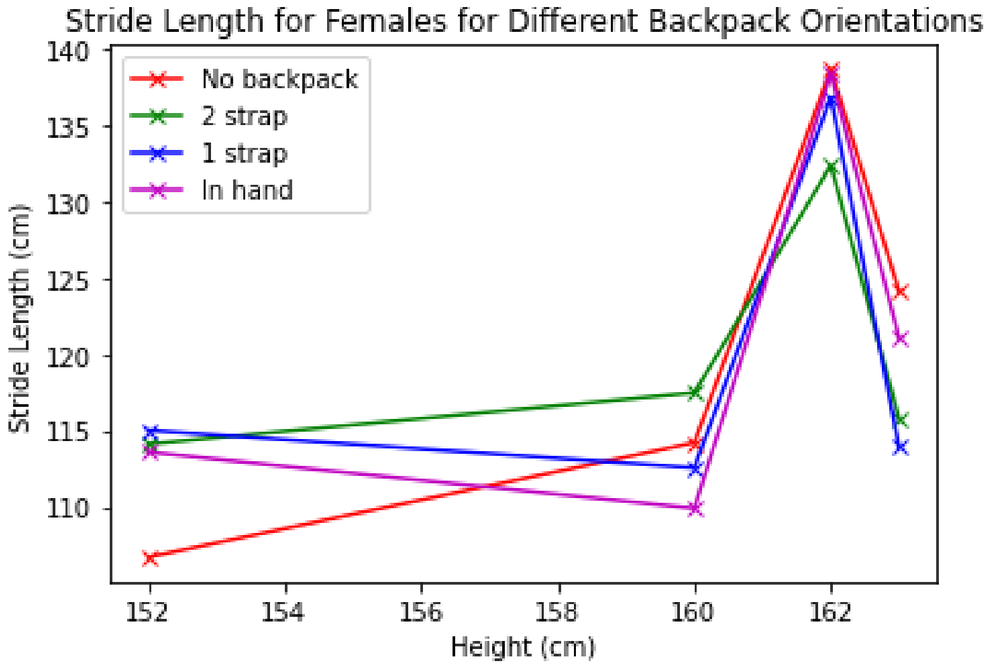
THE STRIDE LENGTH REFERS TO THE DISTANCE BETWEEN IPSILATERAL HEEL STRIKES OF A PERSON. THESE GRAPHS DO NOT APPEAR TO SHOW A SIGINIFICANT RELATIONSHIP BETWEEN STRIDE LENGTH AND DIFFERENT BACKPACK STYLES

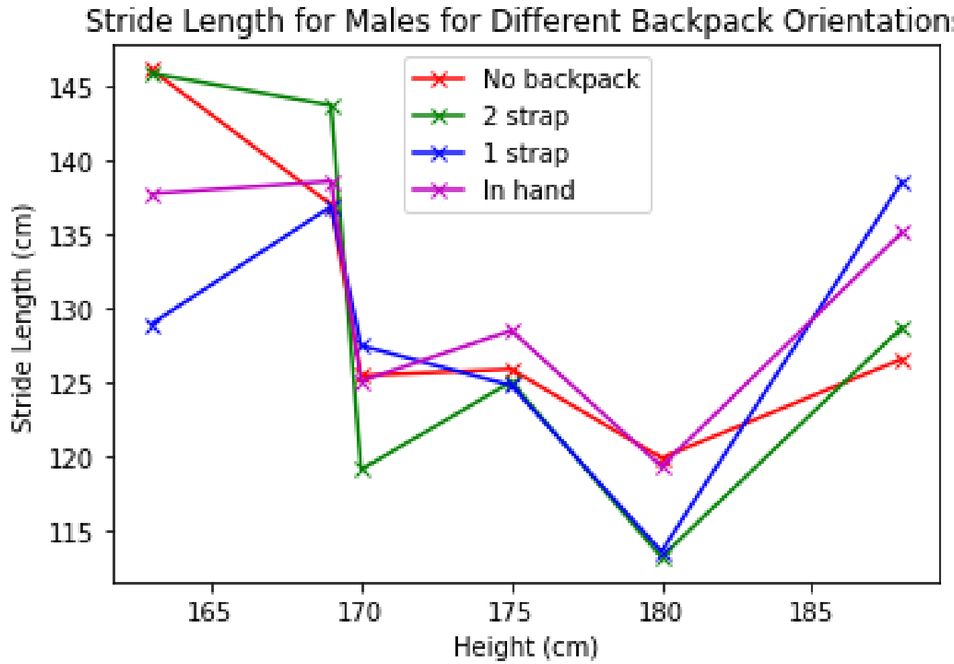




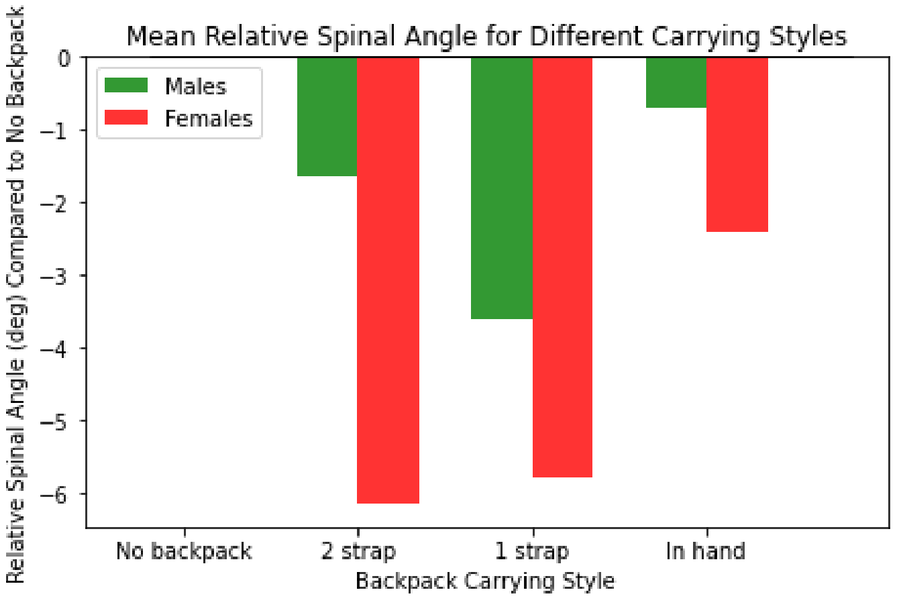
STRIDE LENGTH VS HEIGHT

STRIDE LENGTH APPEARS TO INCREASE WITH HEIGHT FOR FEMALES ALTHOUGH AT THE END, THERE IS A DROP

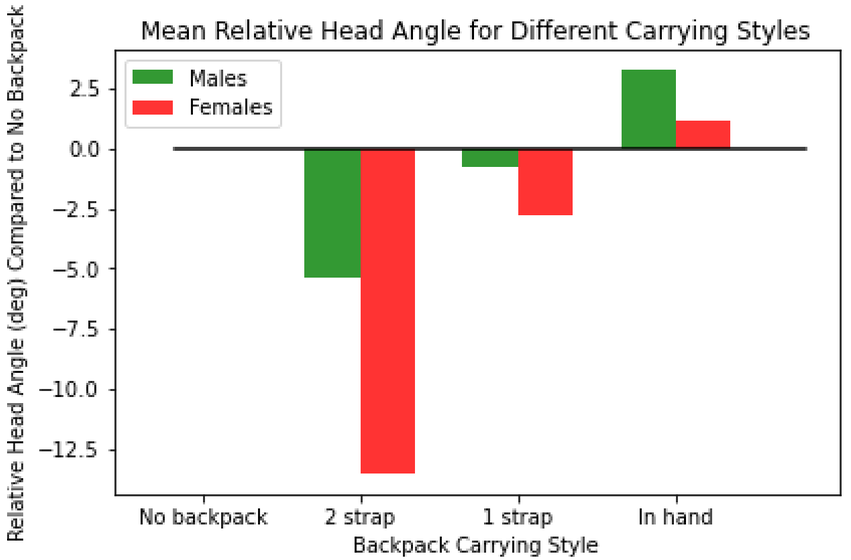




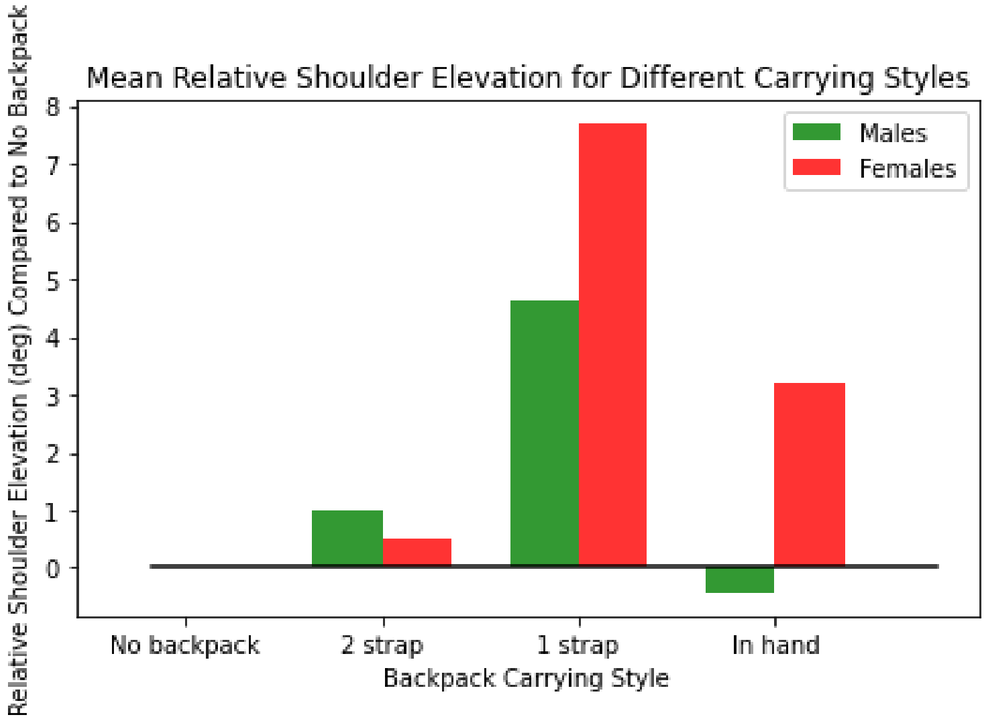
MEAN SPINAL ANGLE



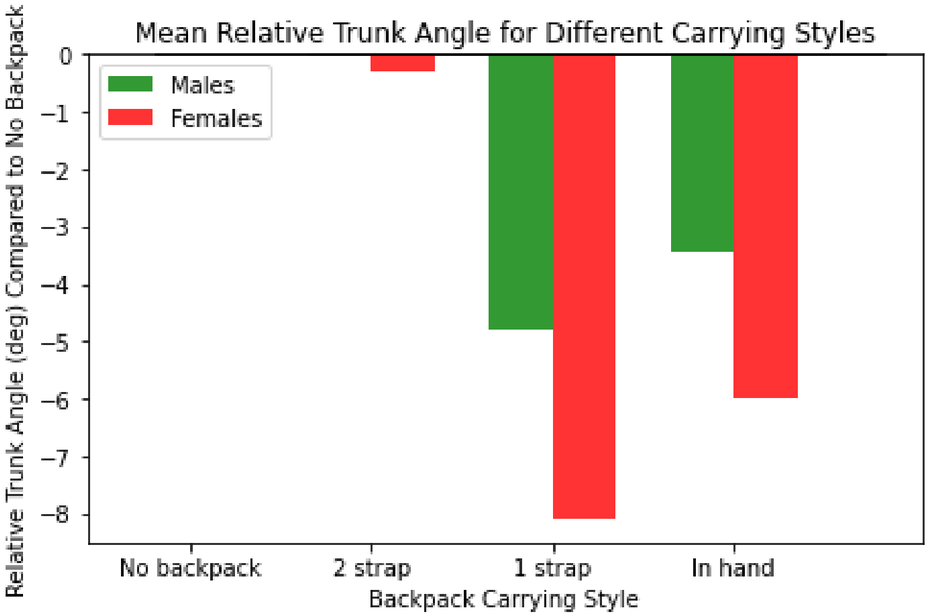
MEAN HEAD ANGLE



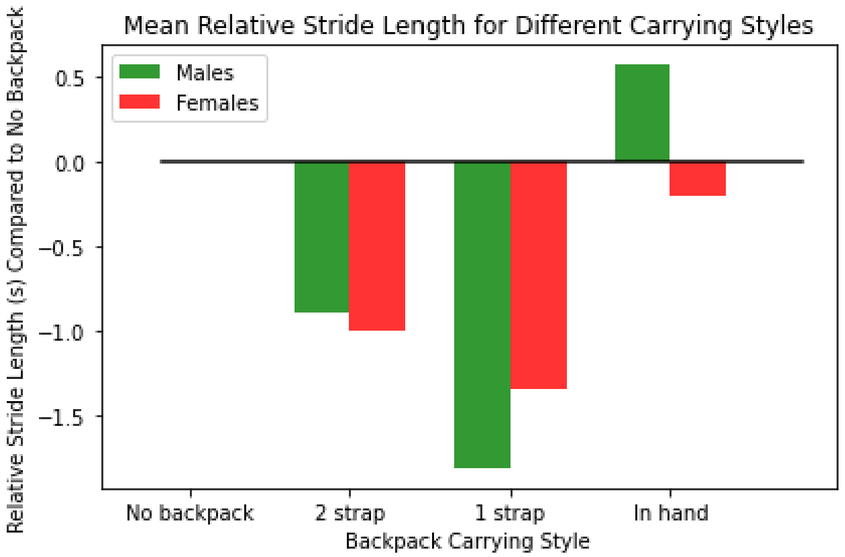
MEAN SHOULDER ELEVATION



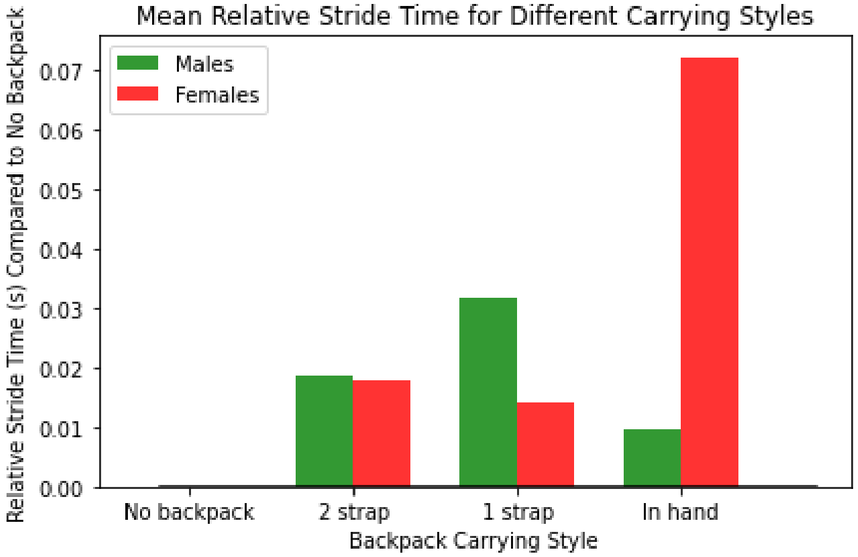
MEAN TRUNK ANGLE



MEAN STRIDE LENGTH



MEAN STRIDE TIME



PAIRED SAMPLE T-TEST

The paired sample t-test formula is given by:

$$[(M\_1 - M\_2) * SQRT(N)] / (S.D.(DIFFERENCE\ BETWEEN\ SAMPLES))$$

Where m_1 is the mean of the first sample, m_2 is the mean of the second sample, n is the sample size and s.d. refers to standard deviation.

- The degrees of freedom are n - 1.
- In this case, n = 10.
- At 95% confidence level, the t value (from the given distribution) is 2.262..

```
print((np.sqrt(10) * (np.average(spinal_angle_no_bag) - np.average(spinal_angle_1strap_bag)) /
       np.std(spinal_angle_no_bag - spinal_angle_1strap_bag)))
print((np.sqrt(10) * (np.average(spinal_angle_no_bag) - np.average(spinal_angle_2strap_bag)) /
       np.std(spinal_angle_no_bag - spinal_angle_2strap_bag)))
print((np.sqrt(10) * (np.average(spinal_angle_no_bag) - np.average(spinal_angle_inhand_bag)) /
       np.std(spinal_angle_no_bag - spinal_angle_inhand_bag)))

print((np.sqrt(10) * (np.average(head_angle_no_bag) - np.average(head_angle_1strap_bag)) /
       np.std(head_angle_no_bag - head_angle_1strap_bag)))
print((np.sqrt(10) * (np.average(head_angle_no_bag) - np.average(head_angle_2strap_bag)) /
       np.std(head_angle_no_bag - head_angle_2strap_bag)))
print((np.sqrt(10) * (np.average(head_angle_no_bag) - np.average(head_angle_inhand_bag)) /
       np.std(head_angle_no_bag - head_angle_inhand_bag)))

print((np.sqrt(10) * (np.average(shoulder_elevation_no_bag) - np.average(shoulder_elevation_1strap_bag)) /
       np.std(shoulder_elevation_no_bag - shoulder_elevation_1strap_bag)))
print((np.sqrt(10) * (np.average(shoulder_elevation_no_bag) - np.average(shoulder_elevation_2strap_bag)) /
       np.std(shoulder_elevation_no_bag - shoulder_elevation_2strap_bag)))
print((np.sqrt(10) * (np.average(shoulder_elevation_no_bag) - np.average(shoulder_elevation_inhand_bag)) /
       np.std(shoulder_elevation_no_bag - shoulder_elevation_inhand_bag)))

print((np.sqrt(10) * (np.average(trunk_angle_no_bag) - np.average(trunk_angle_1strap_bag)) /
       np.std(trunk_angle_no_bag - trunk_angle_1strap_bag)))
print((np.sqrt(10) * (np.average(trunk_angle_no_bag) - np.average(trunk_angle_2strap_bag)) /
       np.std(trunk_angle_no_bag - trunk_angle_2strap_bag)))
print((np.sqrt(10) * (np.average(trunk_angle_no_bag) - np.average(trunk_angle_inhand_bag)) /
       np.std(trunk_angle_no_bag - trunk_angle_inhand_bag)))

print((np.sqrt(10) * (np.average(stride_time_no_bag) - np.average(stride_time_1strap_bag)) /
       np.std(stride_time_no_bag - stride_time_1strap_bag)))
print((np.sqrt(10) * (np.average(stride_time_no_bag) - np.average(stride_time_2strap_bag)) /
       np.std(stride_time_no_bag - stride_time_2strap_bag)))
print((np.sqrt(10) * (np.average(stride_time_no_bag) - np.average(stride_time_inhand_bag)) /
       np.std(stride_time_no_bag - stride_time_inhand_bag)))

print((np.sqrt(10) * (np.average(stride_length_no_bag) - np.average(stride_length_1strap_bag)) /
       np.std(stride_length_no_bag - stride_length_1strap_bag)))
print((np.sqrt(10) * (np.average(stride_length_no_bag) - np.average(stride_length_2strap_bag)) /
       np.std(stride_length_no_bag - stride_length_2strap_bag)))
print((np.sqrt(10) * (np.average(stride_length_no_bag) - np.average(stride_length_inhand_bag)) /
       np.std(stride_length_no_bag - stride_length_inhand_bag)))
```

```
4.554605100034437
3.175802195055486
2.57186165009359
0.7179122808524014
4.233494354903203
-1.257516117488437
-3.874902111989546
-1.576788893838939
-0.9216683512652624
6.305707965362364
0.38400077072897576
5.045324244341582
-1.896747441682902
-1.054722633575667
-1.559899564610472
0.6394406945270734
0.5357316358005139
-0.17088965703023598
```

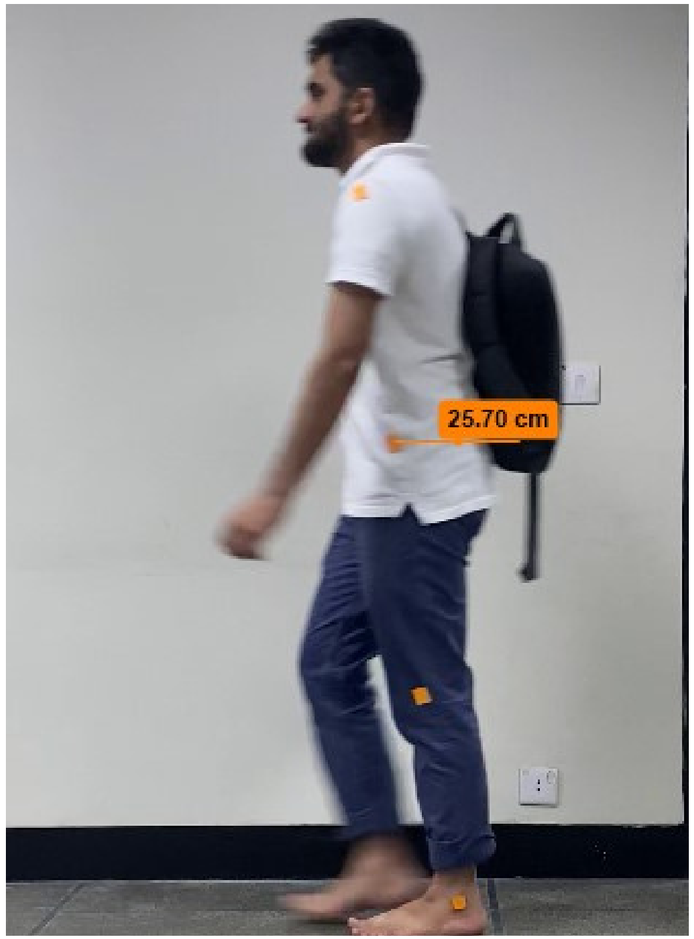
PAIRED SAMPLE T-TEST

CONTINUED

RUNNING THE T-TESTS, WE FIND AT 95% CONFIDENCE LEVEL:

- THE SPINAL ANGLE WITHOUT BACKPACK IS HIGHER THAN THAT WITH 1 STRAP, 2 STRAPS AND THE BACKPACK IN HAND
- THE HEAD ANGLE WITHOUT BACKPACK IS HIGHER THAN THAT WITH 2 STRAPS
- THE SHOULDER ELEVATION WITHOUT BACKPACK IS LESS THAN THAT WITH 1 STRAP
- THE TRUNK ANGLE WITHOUT BACKPACK IS HIGHER THAN THAT WITH 1 STRAP AND THE BACKPACK IN HAND
- THERE IS NO SIGNIFICANT CHANGE IN STRIDE TIME OR STRIDE LENGTH DUE TO CHANGES IN BACKPACK ORIENTATIONS.

KINETIC MEASUREMENT - TORQUE



- The pivot is taken to be the hip joint as indicated by the marker
- The center of mass of the bag is assumed to lie along the line passing through the center of the base of the bag
- The bag pulls the wearer backwards, leading to a clockwise torque on the torso of the person
- The person, in most cases, would try to lean forward to counter this torque

MOMENT ARM = 25.70 CM = 0.257 M
TORQUE = 7.3 * 9.81 * 0.257 = 18.4 Nm

RESULTS & RECOMMENDATIONS

WEAR BOTH THE STRAPS OF YOUR BACKPACK

- Our results show that the ideal posture is better retained when individuals wear two straps instead of one or when they hold the backpack

KEEP THE STRAPS OF YOUR BACKPACK TIGHT

- Keeping the straps tight reduces moment arm and subsequently reduces the torque as well
- This reduces the forward lean to counter the torque

CHOOSE BACKPACKS WITH WIDE STRAPS

- Wide straps increase the surface area on the shoulders leading to less pressure on the flesh

TRY TO MAINTAIN A STRAIGHT BACK

- Regardless of the clockwise torque due to the backpack, maintaining a straight back reduces curvature of the spine

LIMITATIONS

LIMITED SAMPLE SIZE

- The sample size only consisted of 10 participants which makes it difficult for us to generalize our results

POOR MARKER VISIBILITY, POSITIONING AND PLACEMENT

- Difficult to identify marker in video when participants wore bright colored clothes or those similar to the color of the paper
- Some participants wore loose clothes which moved the position of the markers away from the joints during their gait cycle
- Some markers occasionally fell off during the experiment, hence we were never sure if we placed them back in the exact same position

UNNATURAL GAIT

- Participants displayed visibly unnatural gait as they were being observed during the experiment
- Some participants began overcompensating when they were placed under to the load to maintain a 'perfect' posture

LIMITATIONS

CONTINUED

EMG MEASUREMENTS

- Deeper muscular analysis of the gait cycle and posture control could have been possible
- Further information could have been extracted to learn more about the role muscle activation plays in maintaining posture under load

APPENDIX

- *PASCOE, DAVID D., et al. “Influence of Carrying Book Bags on Gait Cycle and Posture Of Youths.” Ergonomics, vol. 40, no. 6, 1997, pp. 631–640., doi:10.1080/001401397187928*

- *https://colab.research.google.com/drive/1tRtR8FblMyNX8gf-o7RTOZQa8RJUSSoS?usp=sharing*

- *https://github.com/hanis26/Gait-Analysis*