Jump Detection Using Floor Vibrations

CEE 5440

Final Presentation

Tasha Vipond

Engineering Challenge

- Measuring jump count is a valuable metric for evaluating fatigue of volleyball players
- Current jump detections devices are:
  - Expensive
  - Worn by individuals
- Form a cost-effective alternative that still accurately counts jumps

27.4 in
9:41 AM
100%
Evelyn
Jumper
Best
31.5
Average
22.7
Amount
85
VIDEO
27.4”
PIC

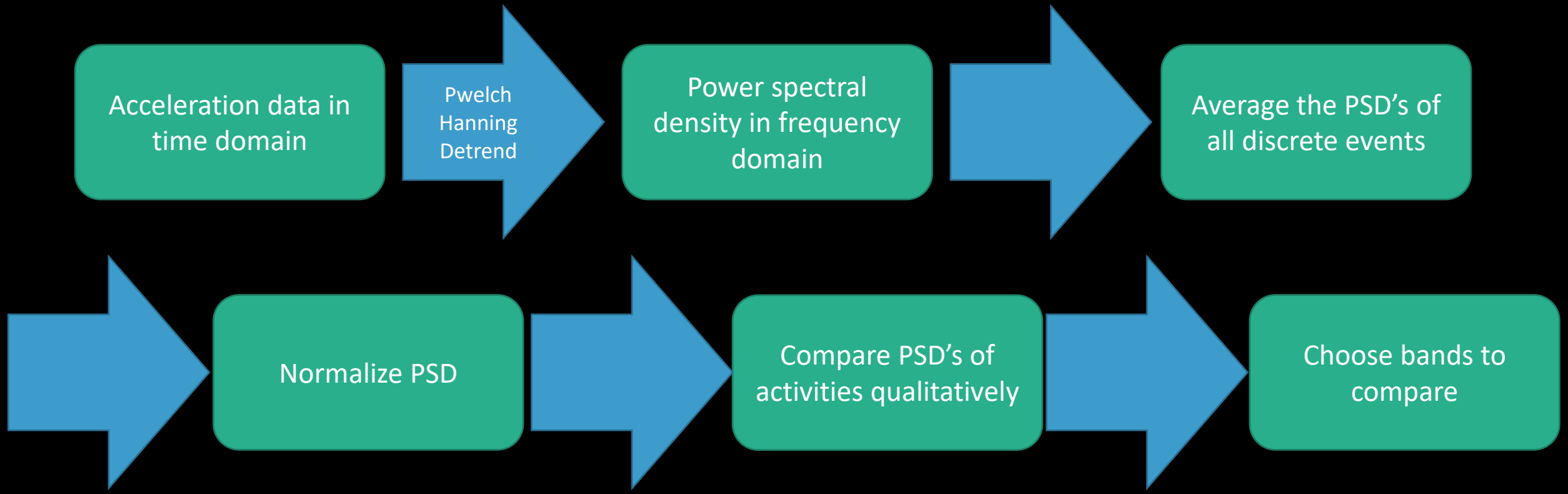
Hypothesis/ Objective

- Correctly identify when jumps (blocking and hitting) occur
- Minimize misidentification of walking, running, and balls hitting the floor
- Determine total jump count based on jumping events detected

Data Collection

- 3-axis digital accelerometer on LSM6DS3
- Z-axis
- 833 Hz
- 60 seconds
- Isolated activities

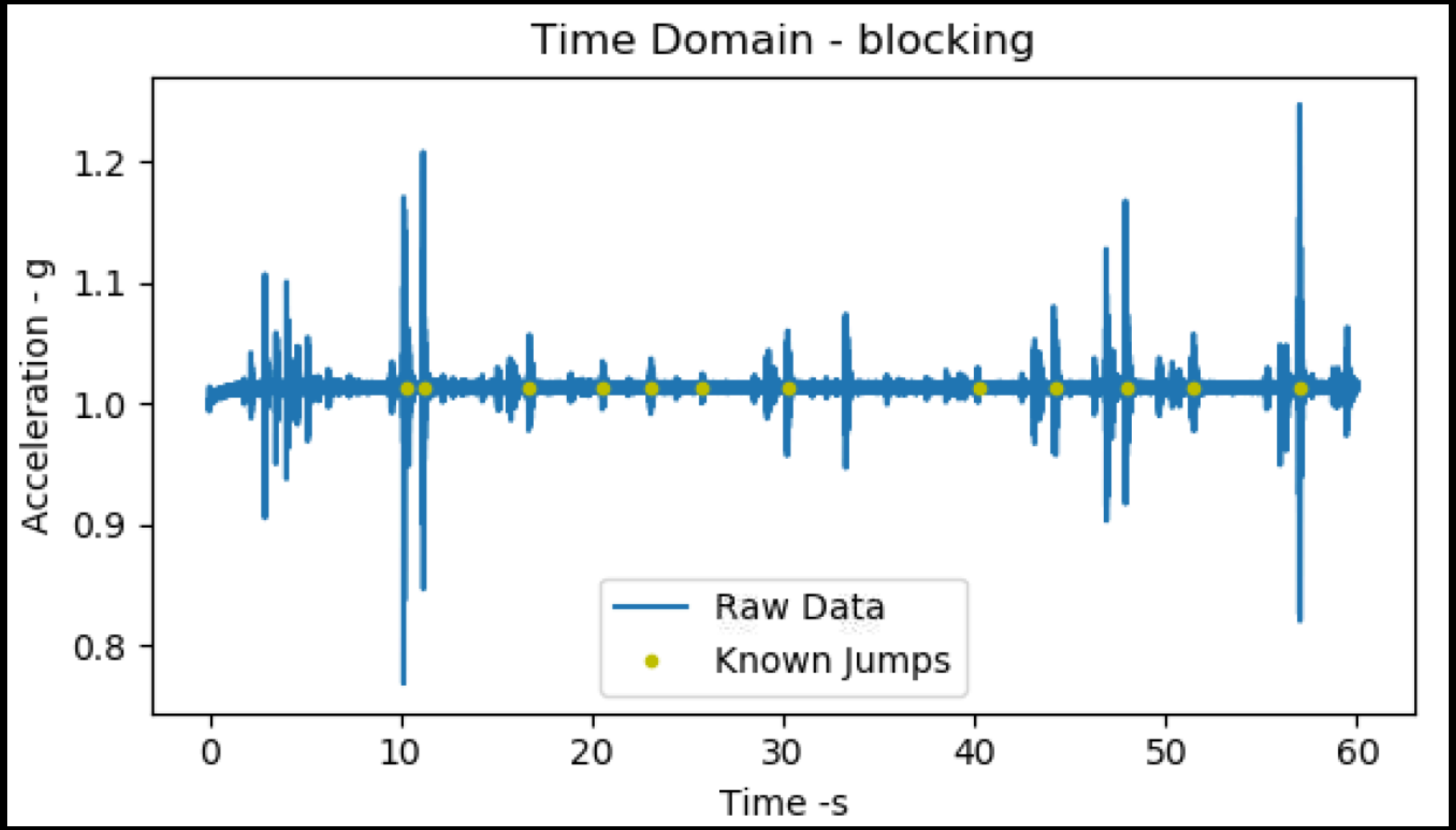
Procedure – Determining Threshold



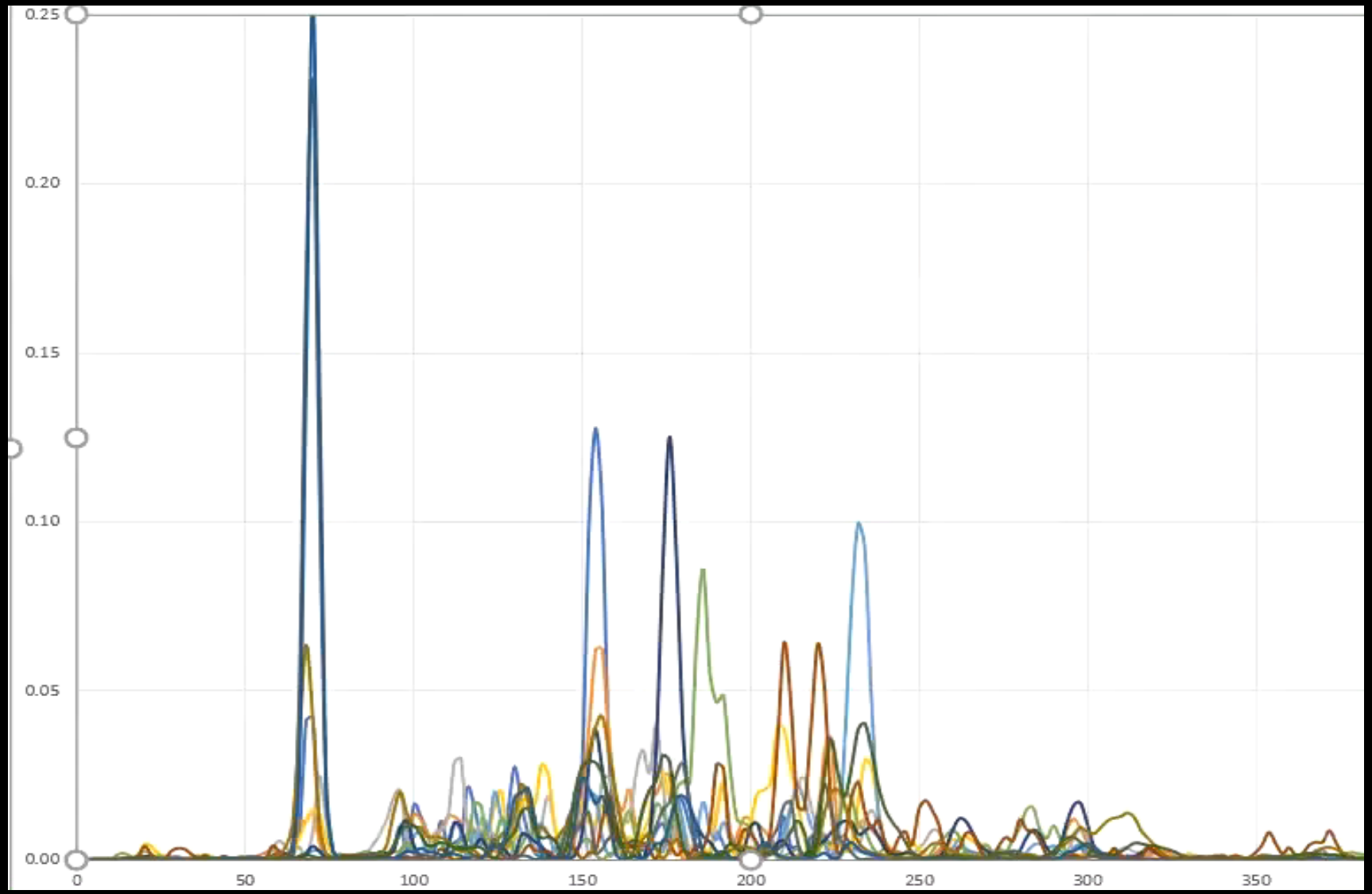
Determining Threshold

- Continuous events
  - Walking
  - Running
  - Ambient noise
- Discrete events
  - Block jumps
  - Hitting jumps
  - Balls hitting floor

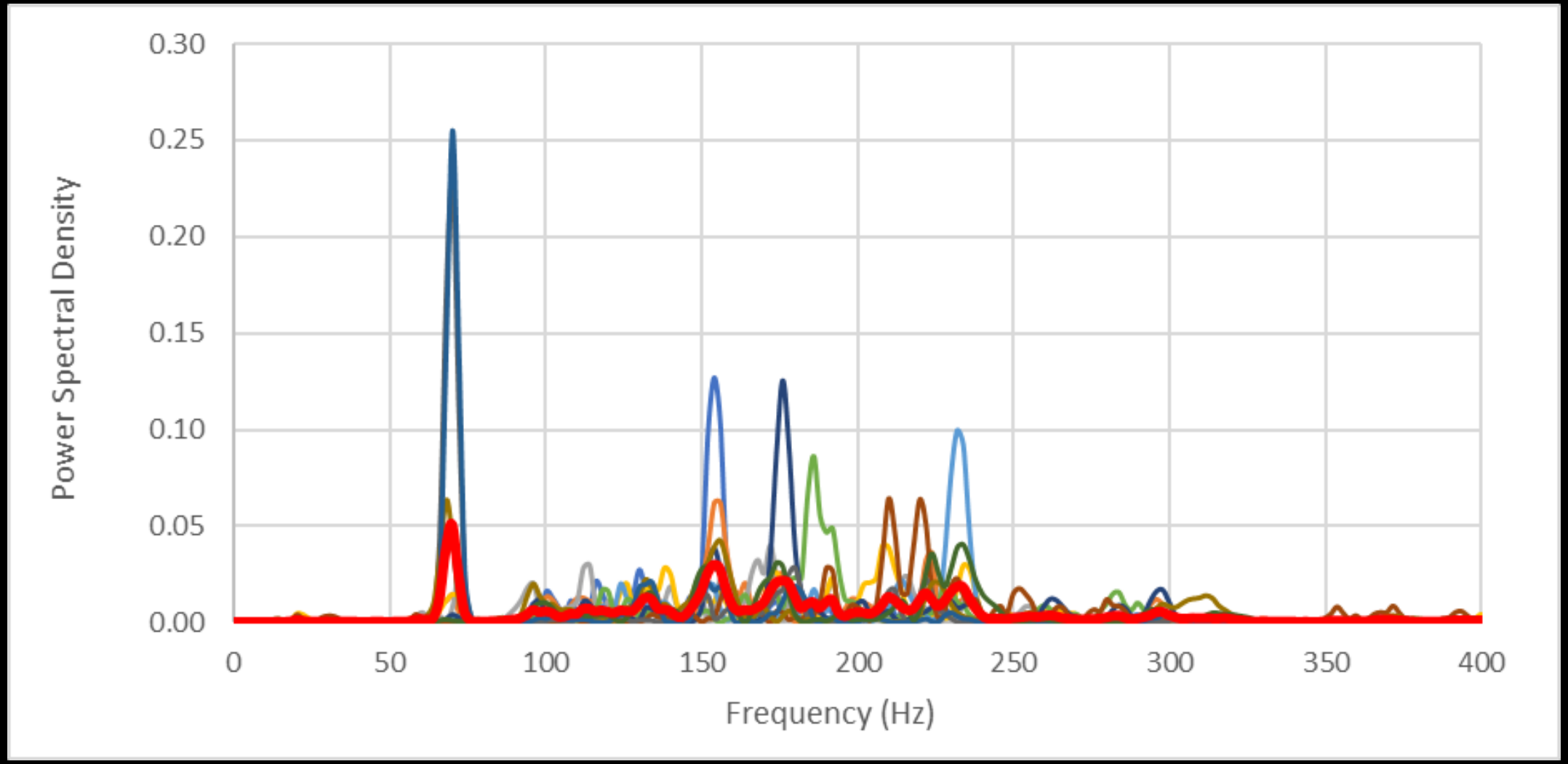
Discrete Event - Blocking



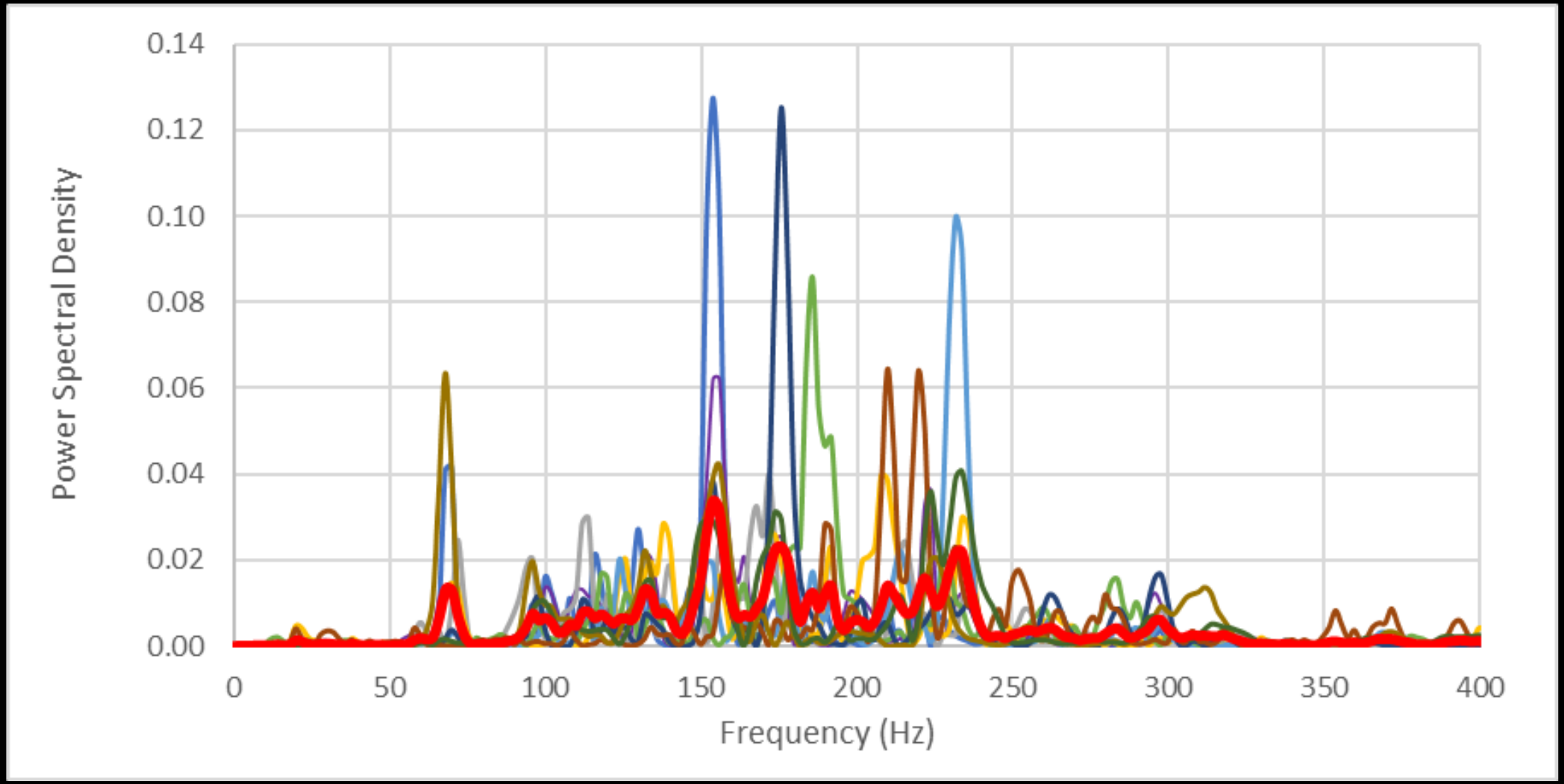
Discrete Event - Blocking



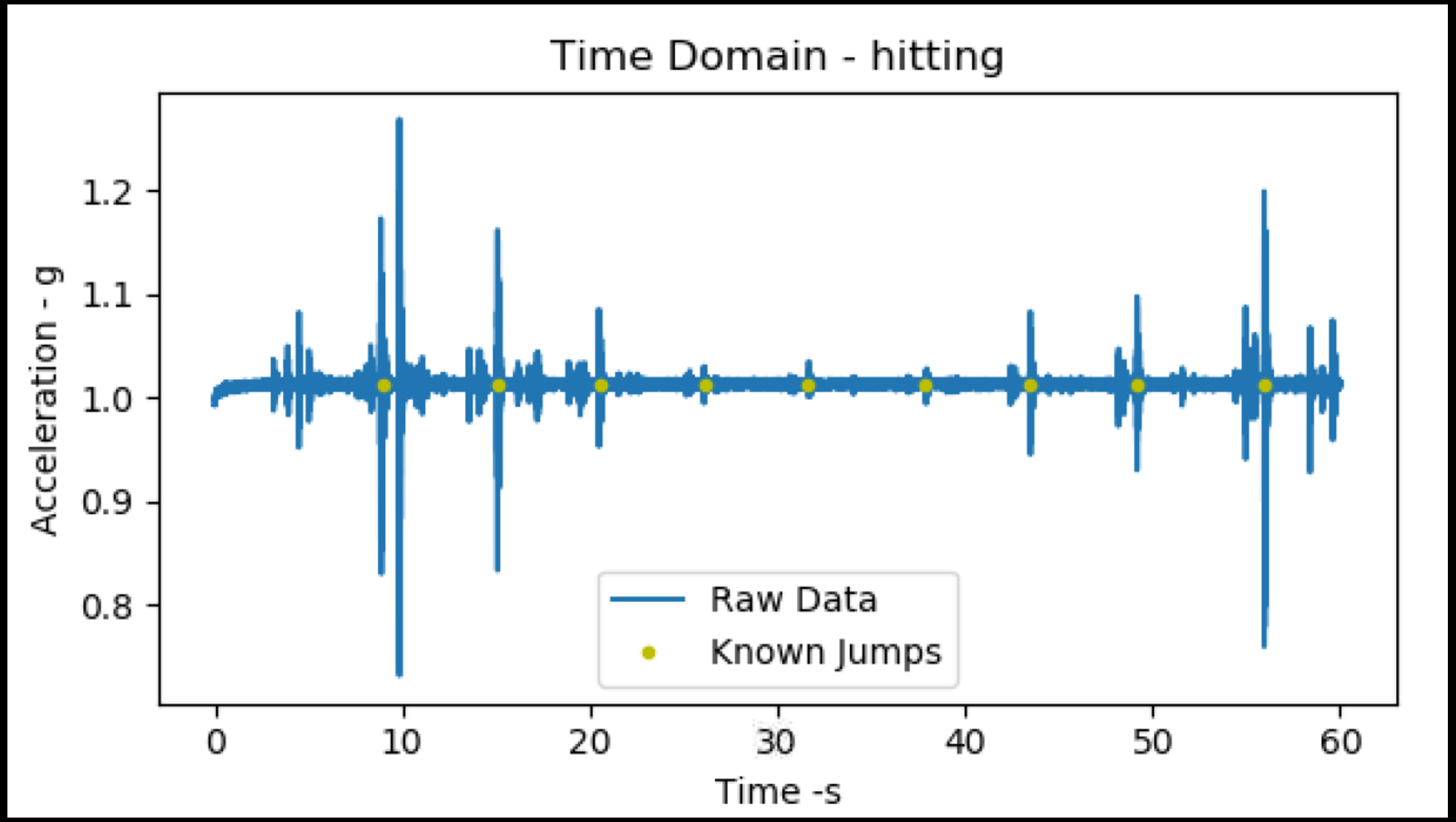
Discrete Event - Blocking



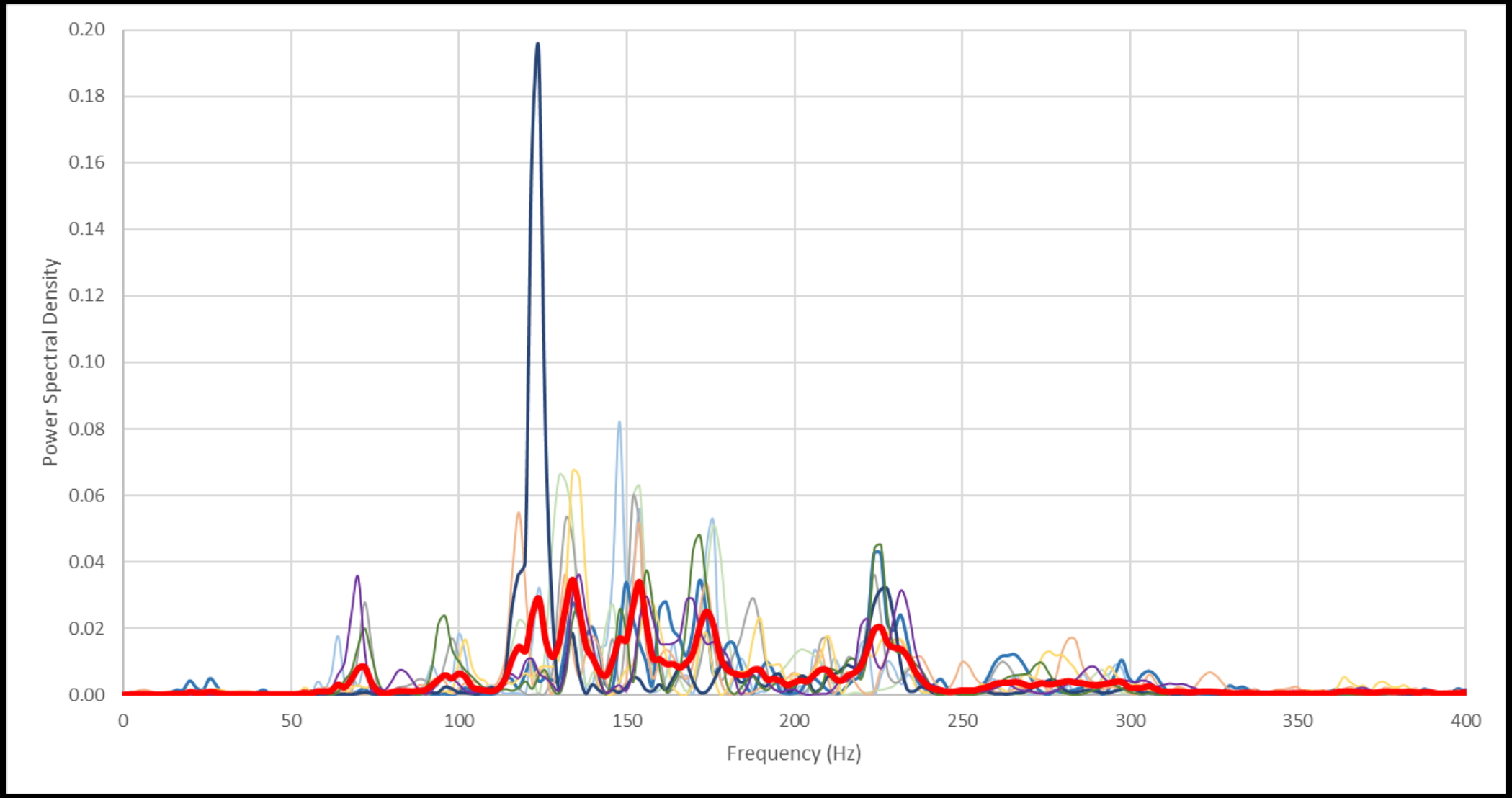
Discrete Event - Blocking



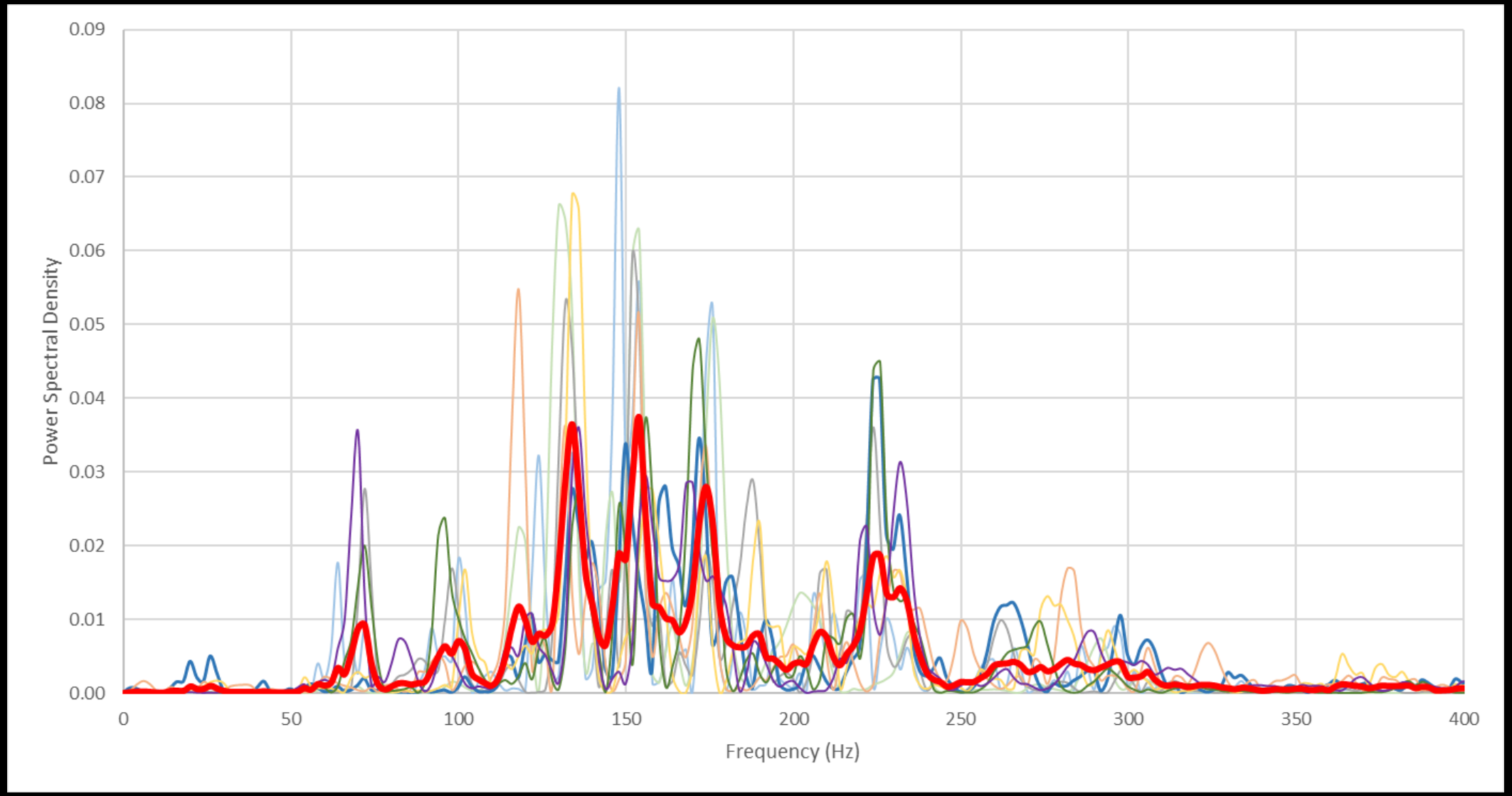
Discrete Event - Hitting



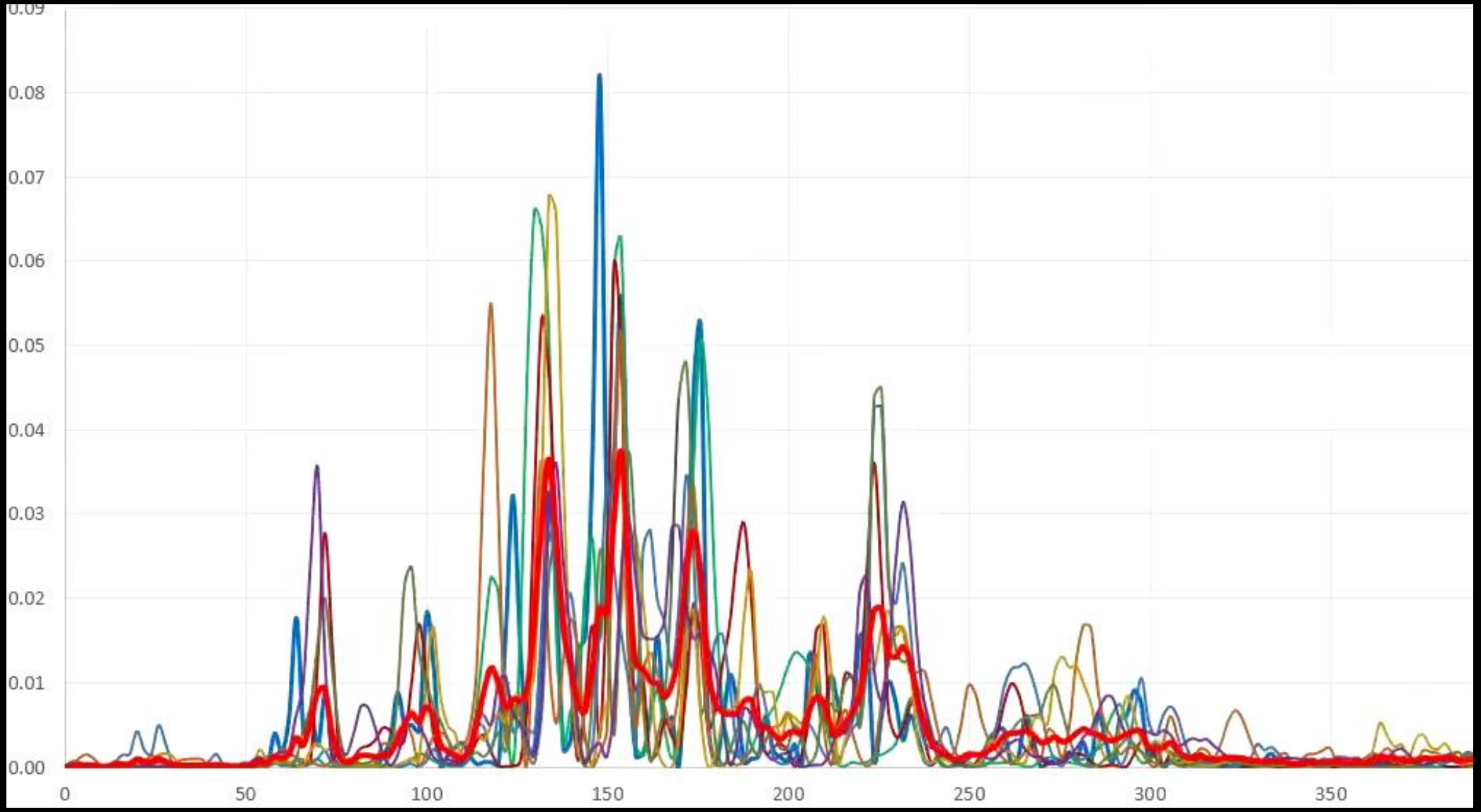
Discrete Event - Hitting



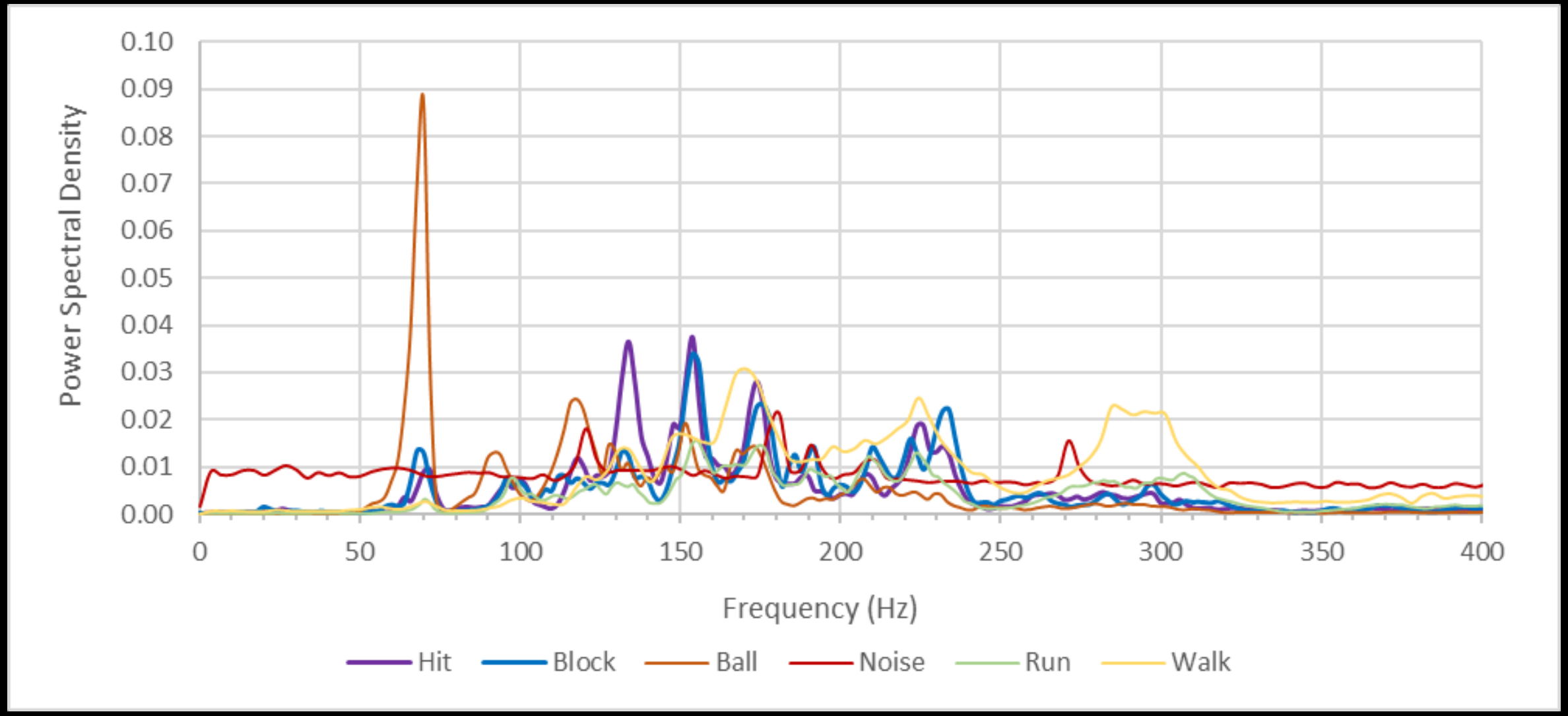
Discrete Event - Hitting



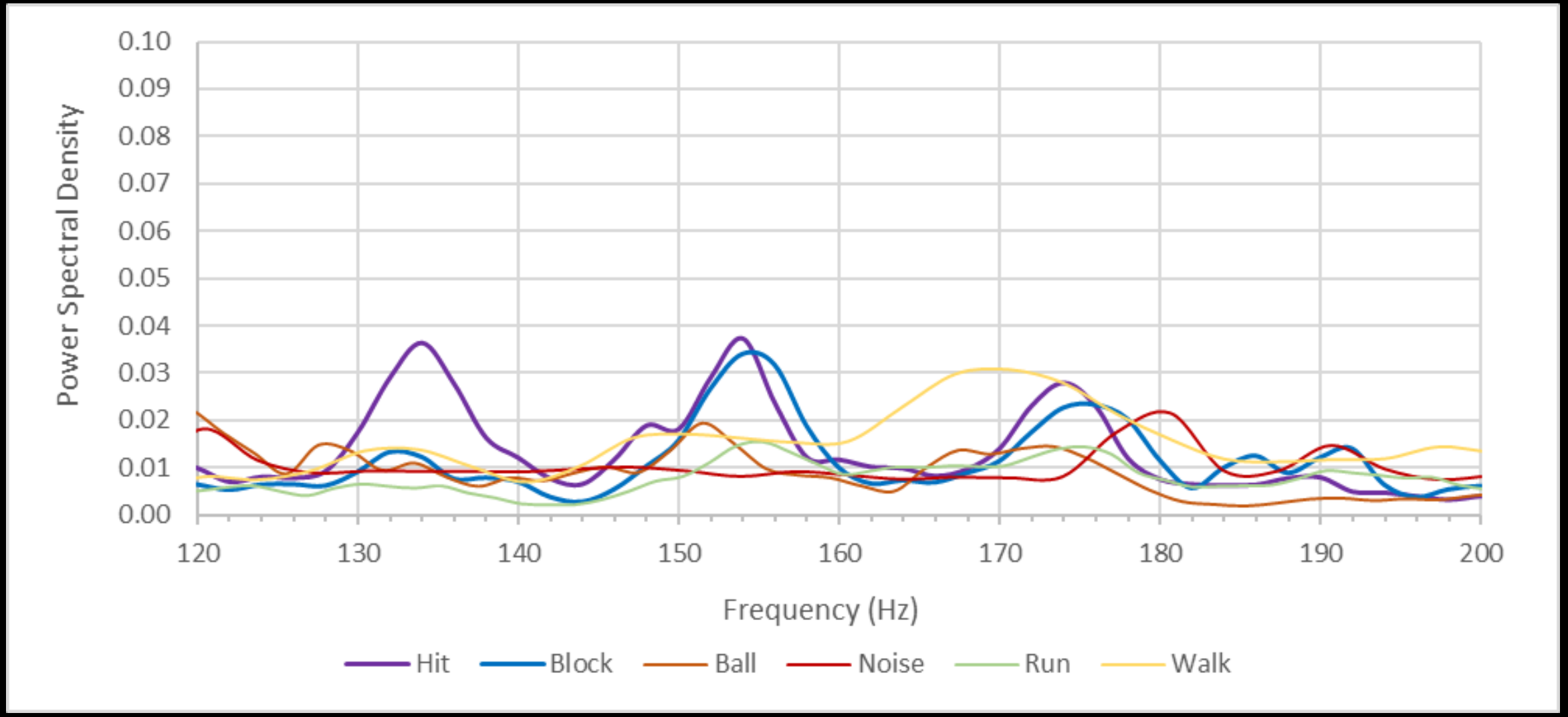
Discrete Event - Hitting



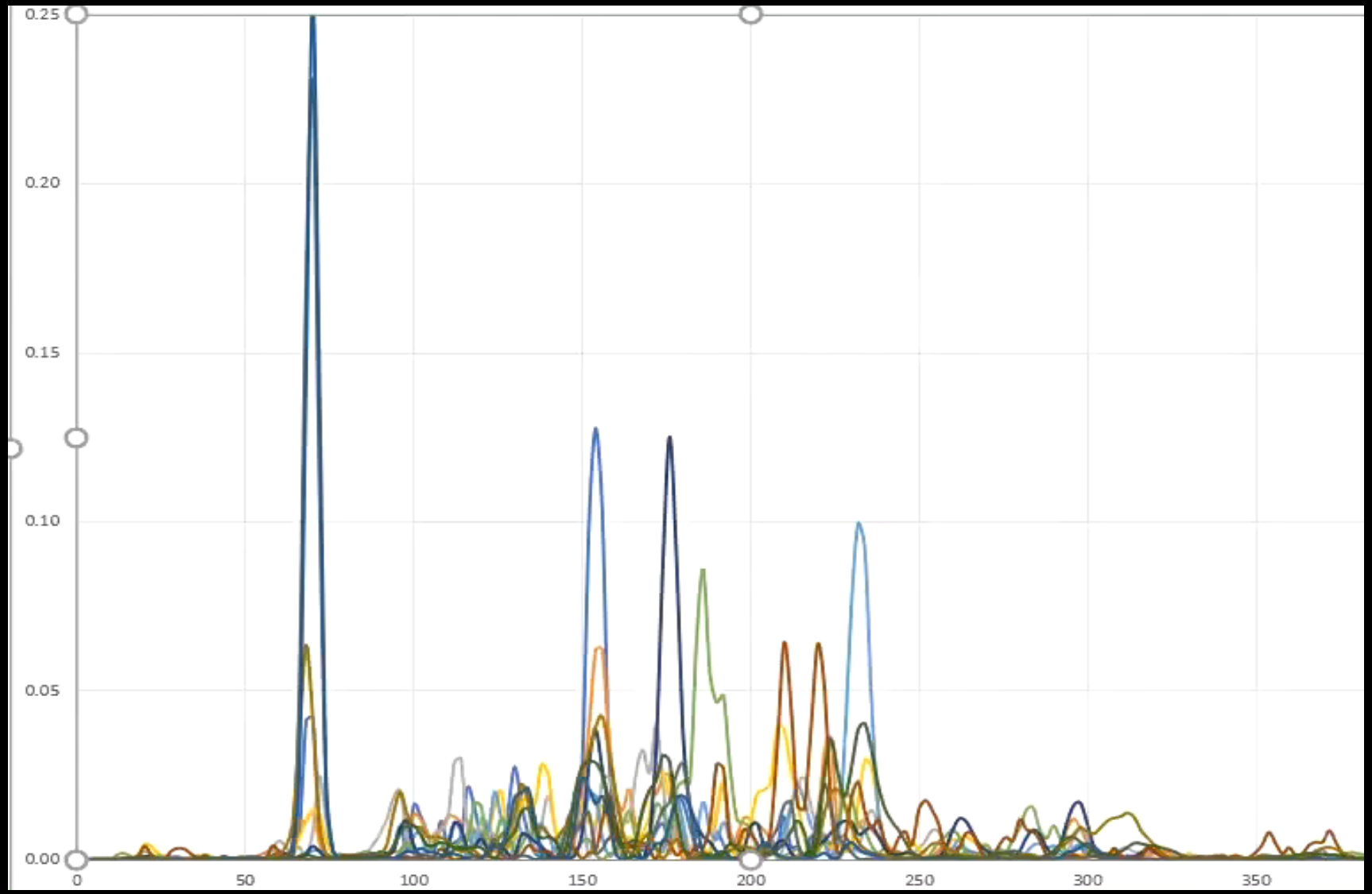
PSD Comparison



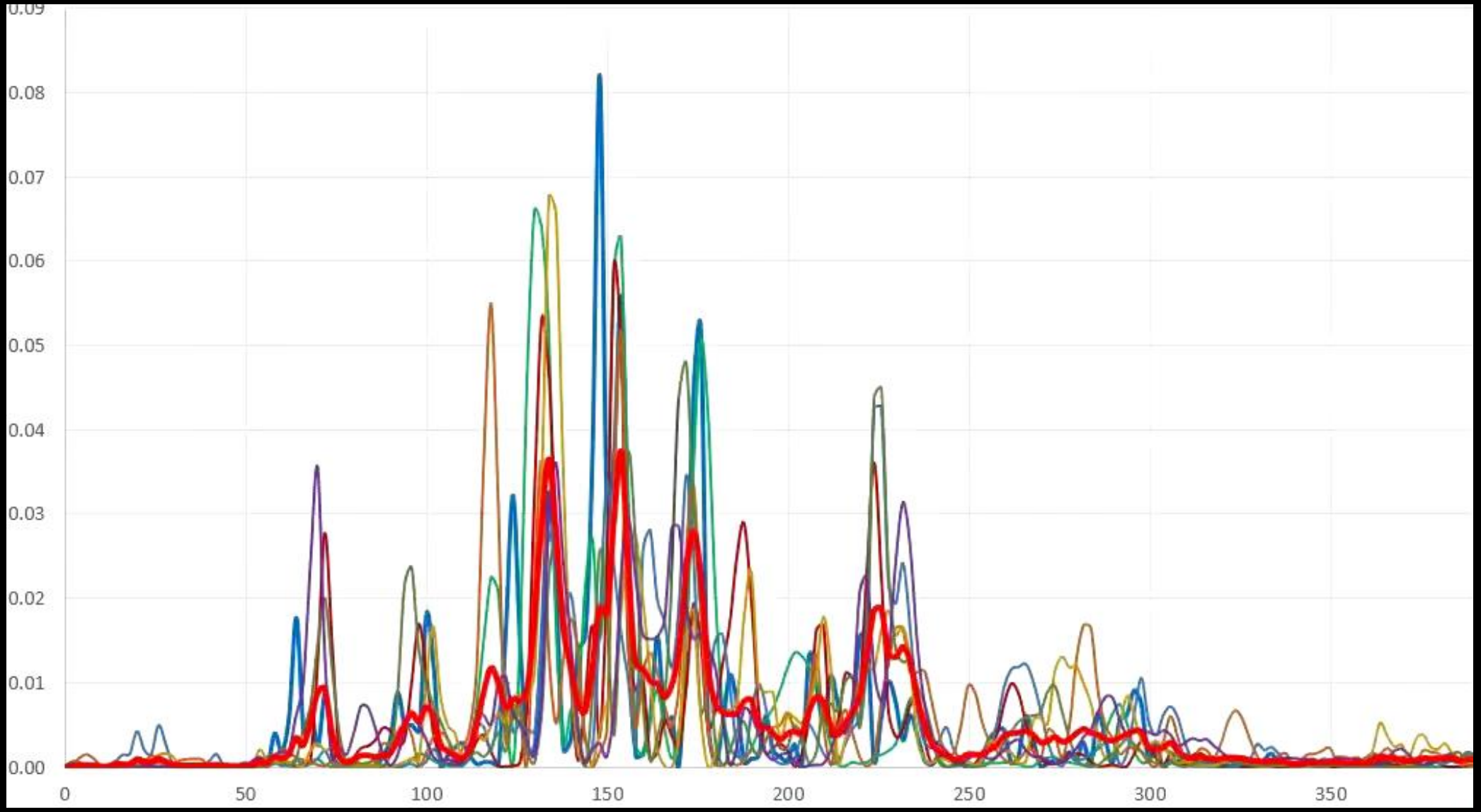
PSD Comparison



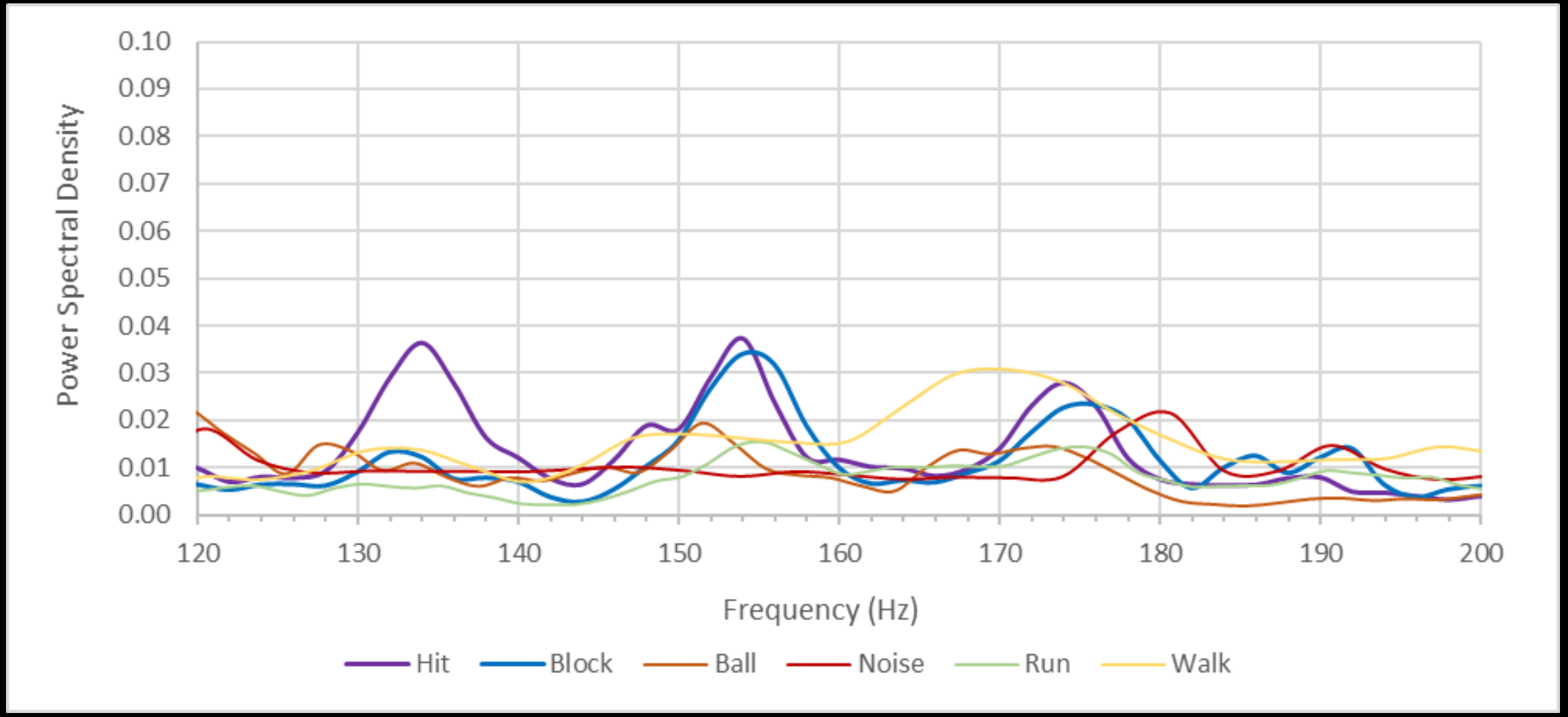
Blocking



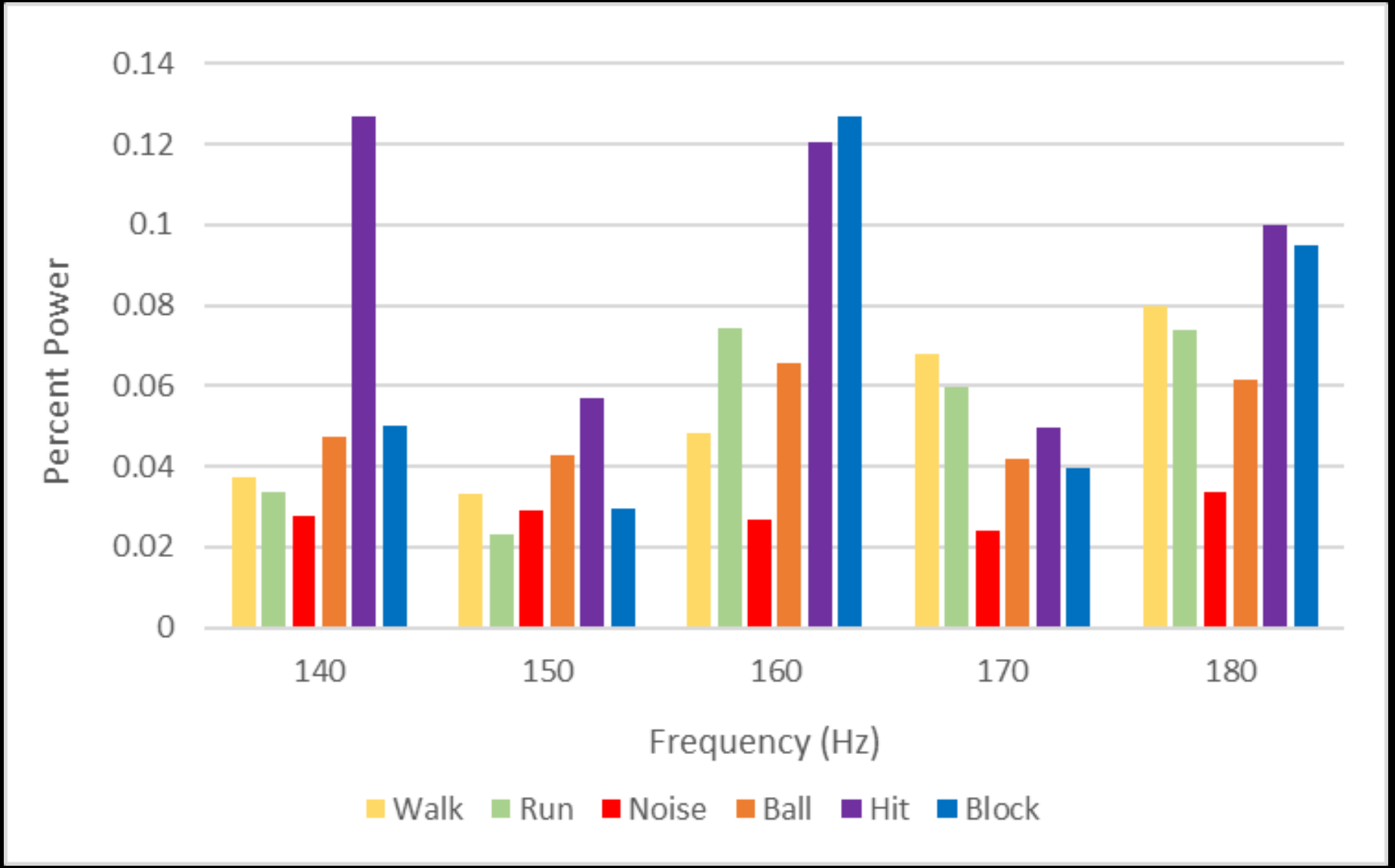
Hitting


0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
50
100
150
200
250
300
350

PSD


Power Spectral Density
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
120
130
140
150
160
170
180
190
200
Frequency (Hz)
Hit
Block
Ball
Noise
Run
Walk

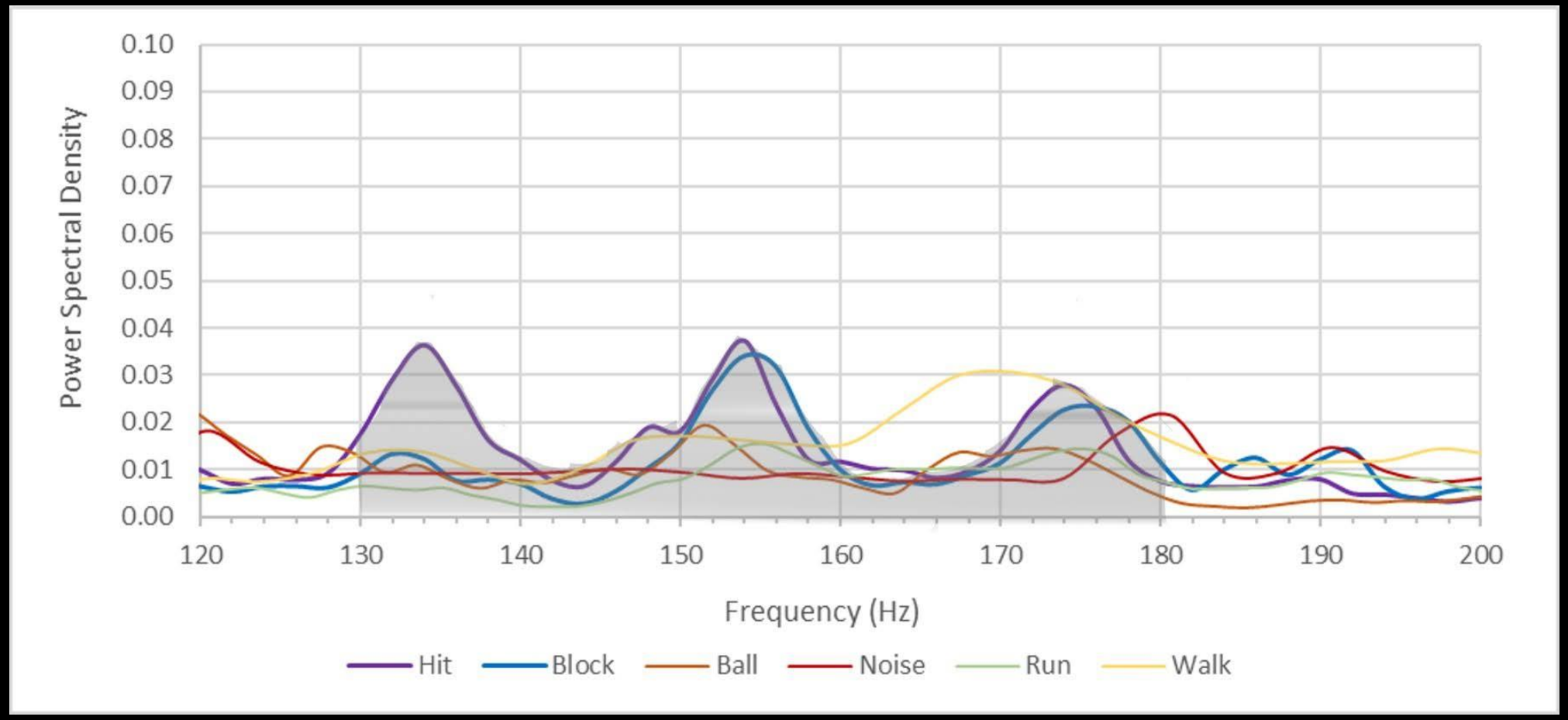
Band Power



$$\delta f \sum S_{xx}[k]$$

Normalize by total power

Option 1: Integrate Full Range



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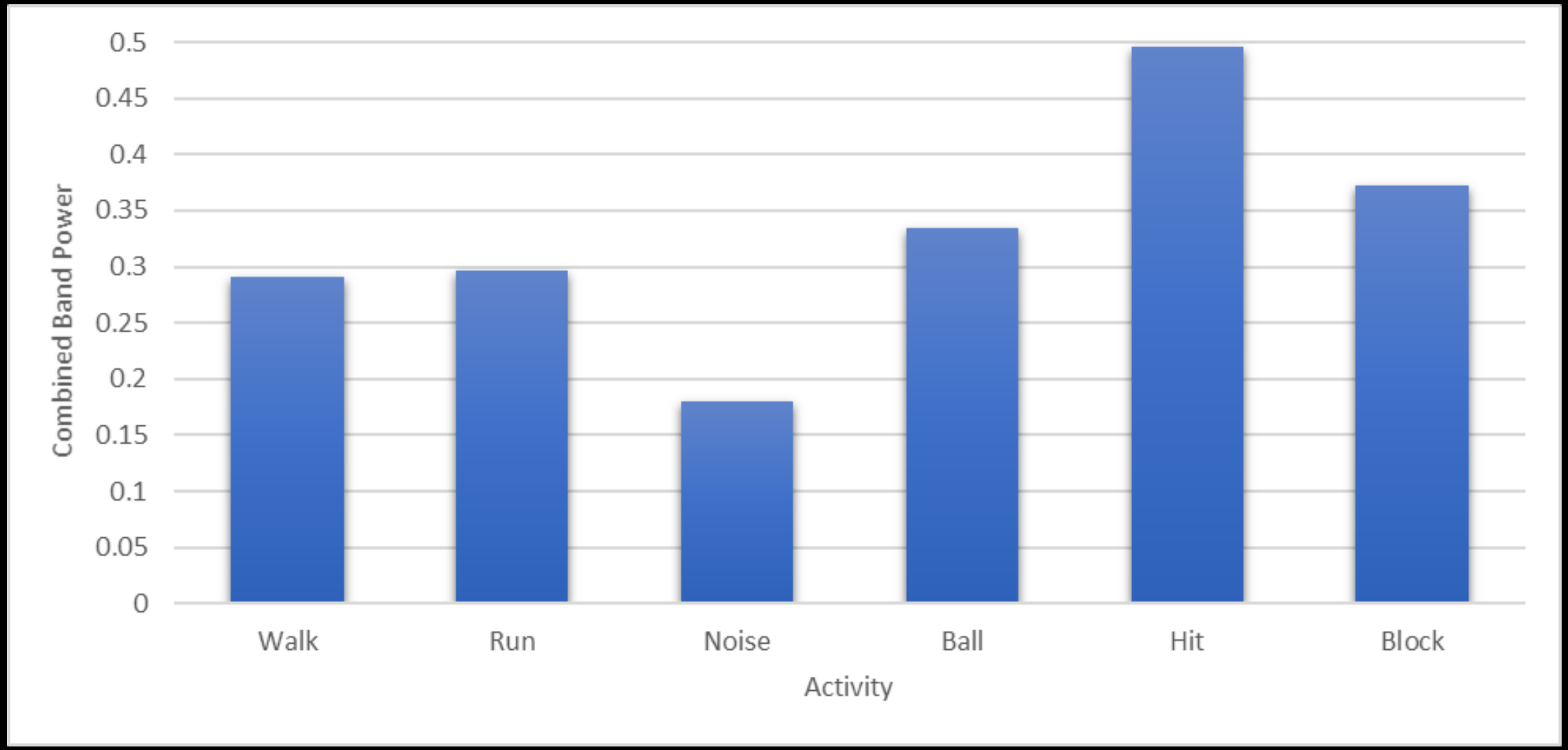
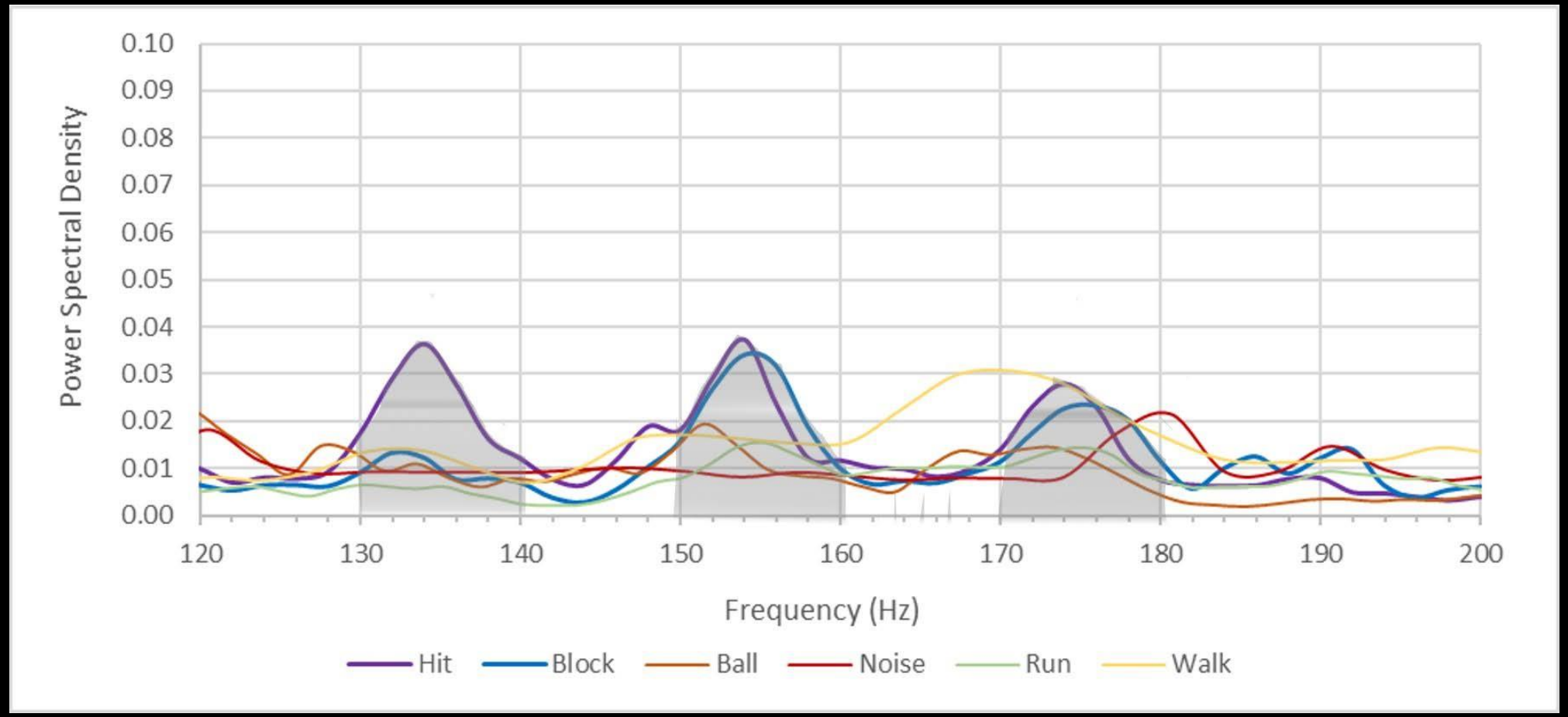
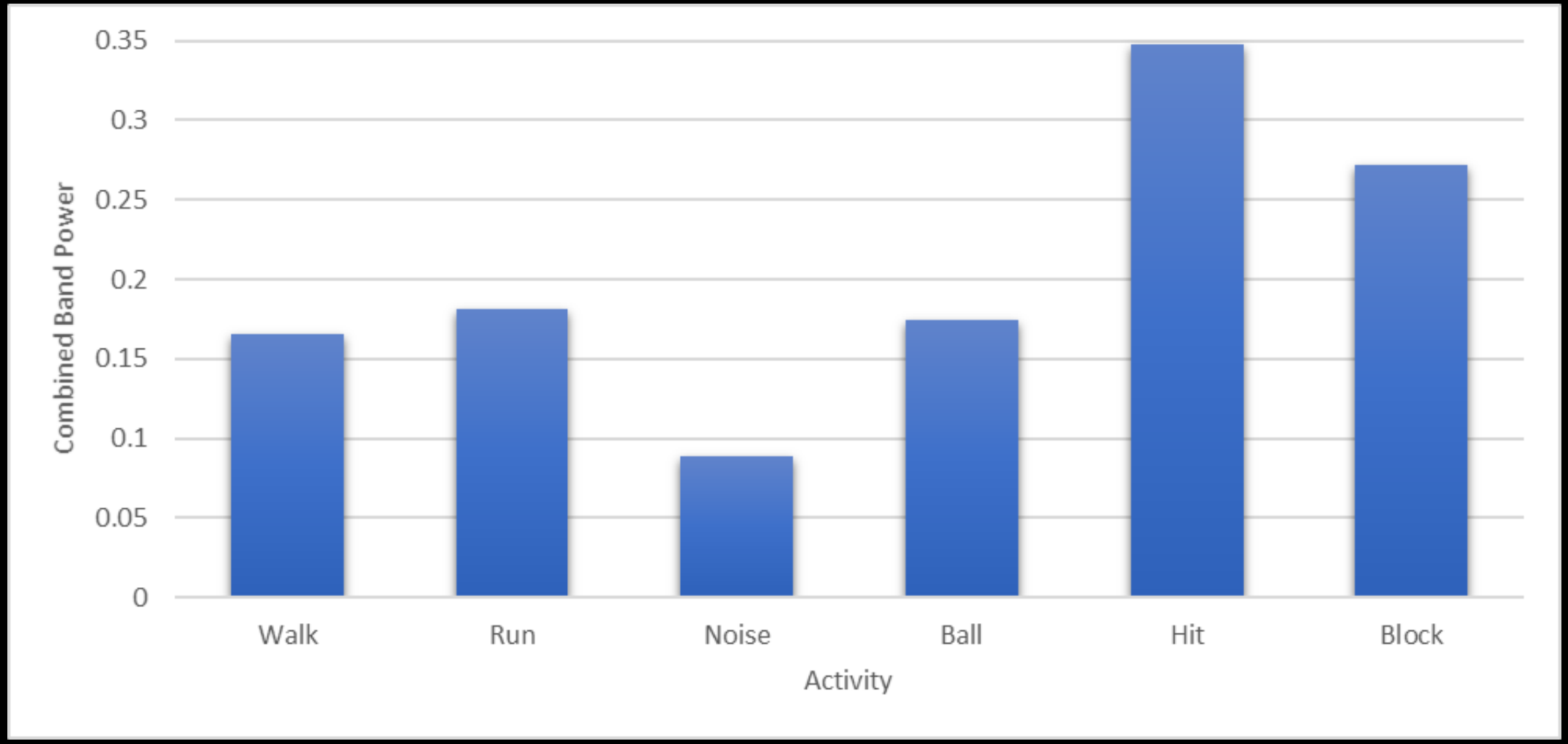


Option 2: Selectively Integrate



Option 2: Selectively Integrate



Event Detection – Change in Variance Test

$$\delta f \sum S_{xx}[k]$$

$$\chi_k^2 = \frac{(N-1)s_k^2}{\sigma_0^2}$$

$$\chi_k^2 \geq \beta * 2(N-1)$$

Combined Band Power (Hz)						
	Walk	**Run**	**Noise**	**Ball**	**Hit**	**Block**
130-180	0.291	0.297	0.180	0.335	0.496	0.372
Select	0.165	0.182	0.088	0.175	0.348	0.272

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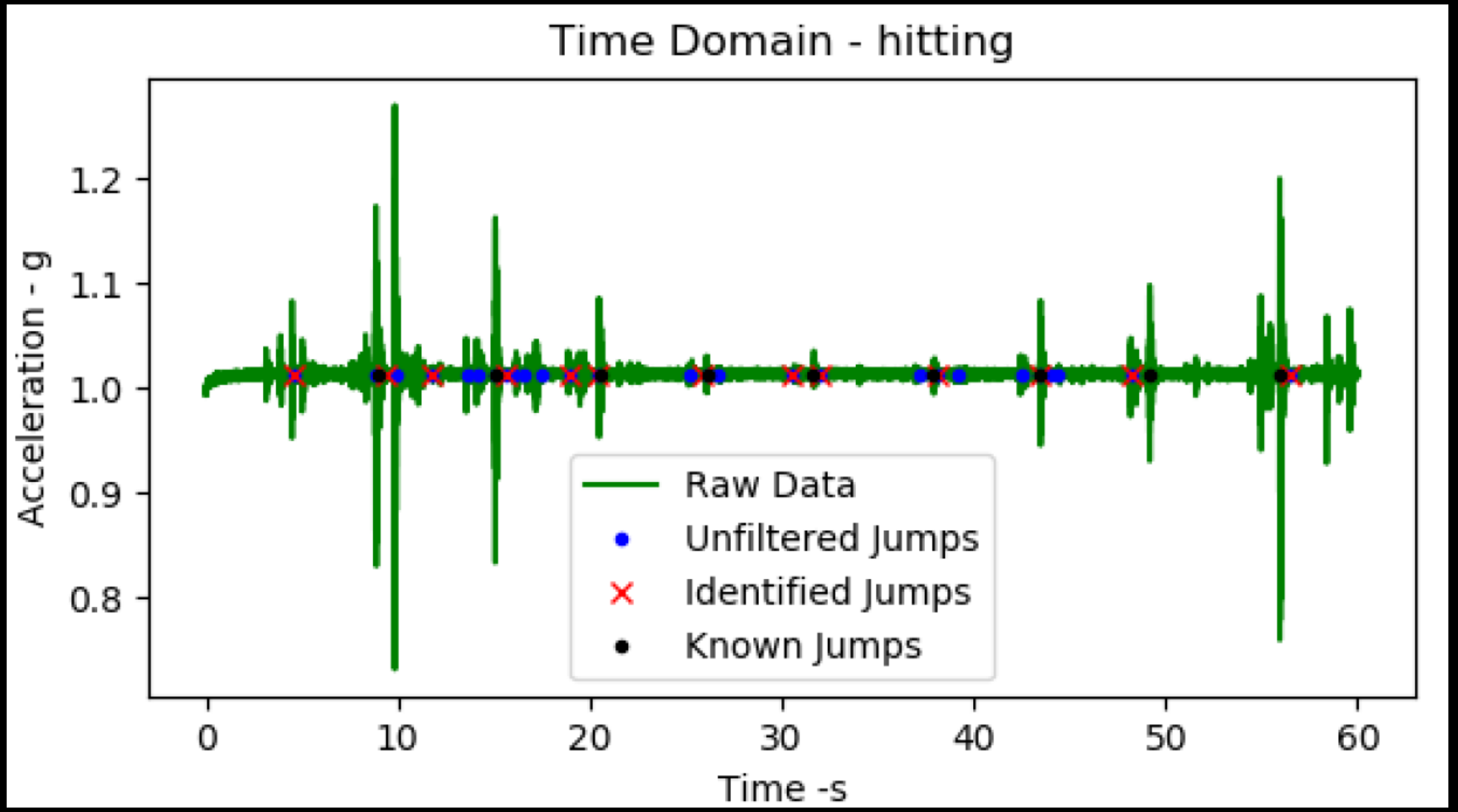
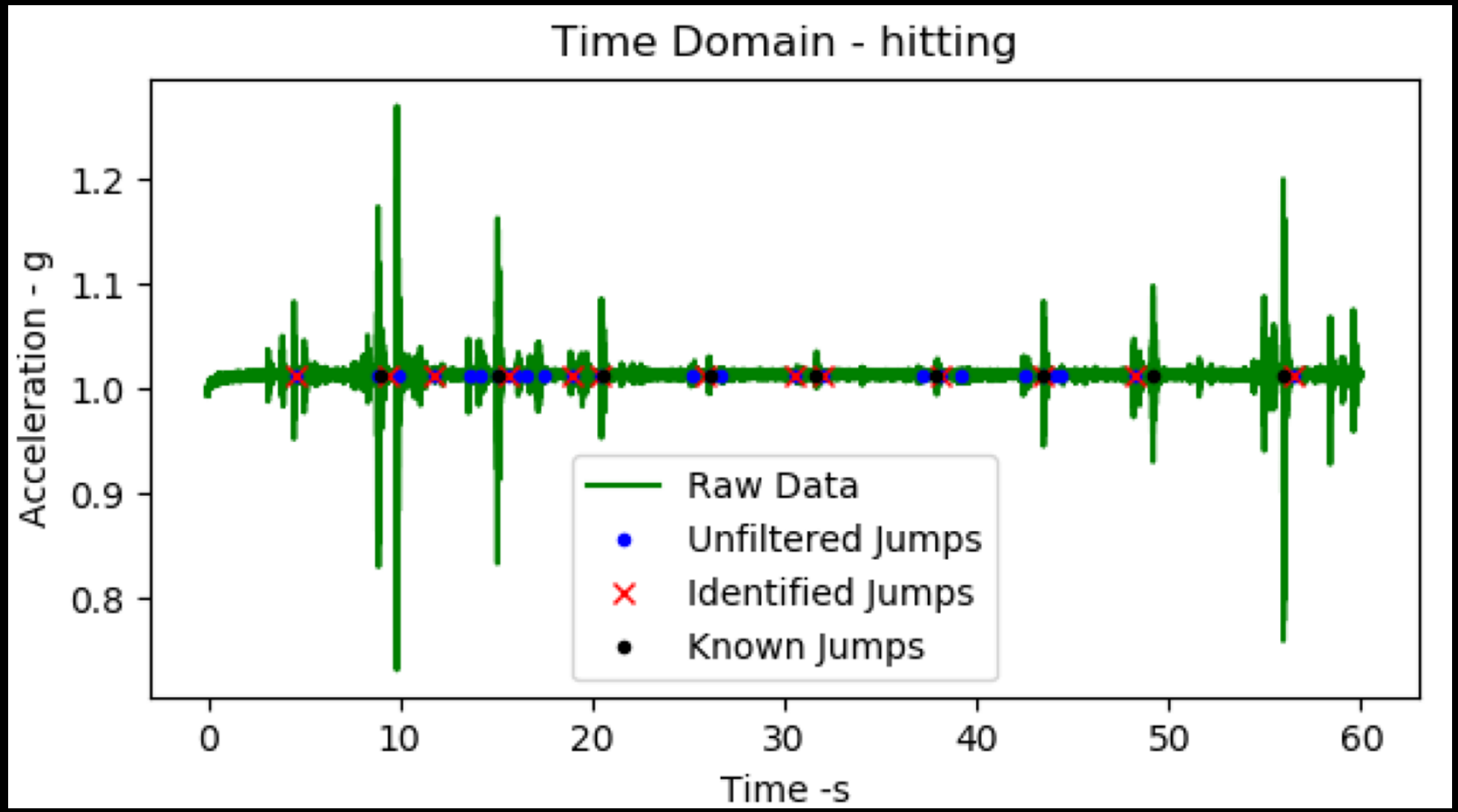
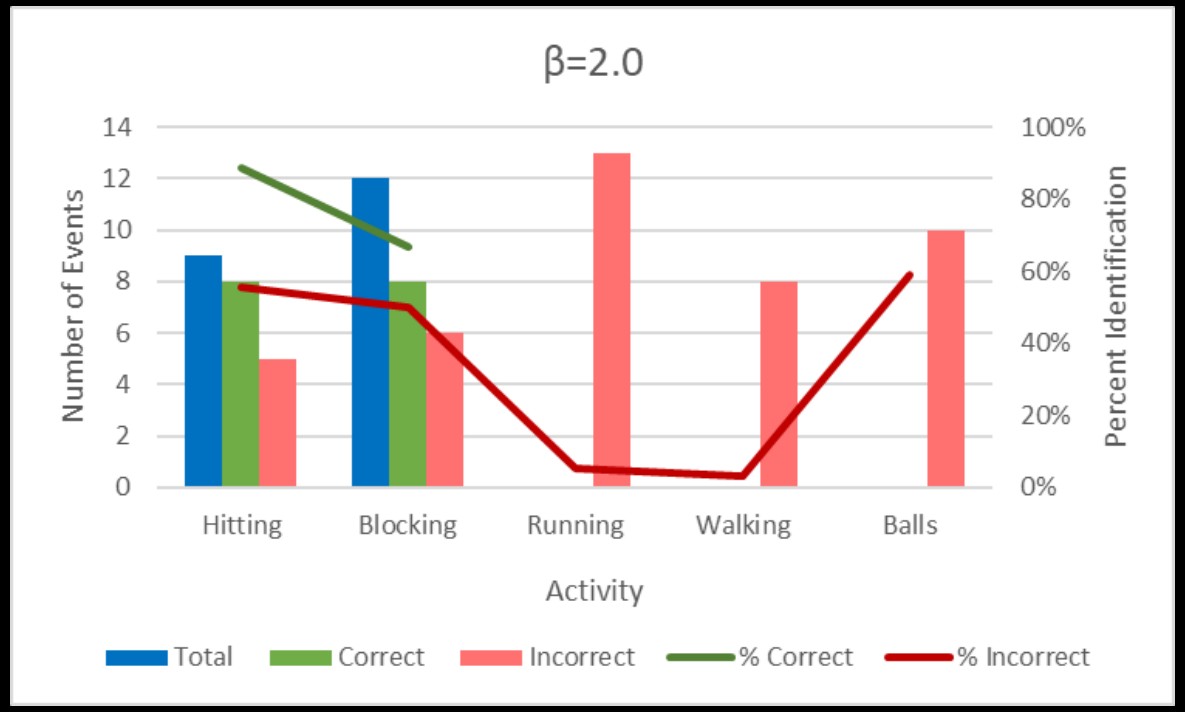
Using Jump Characteristics

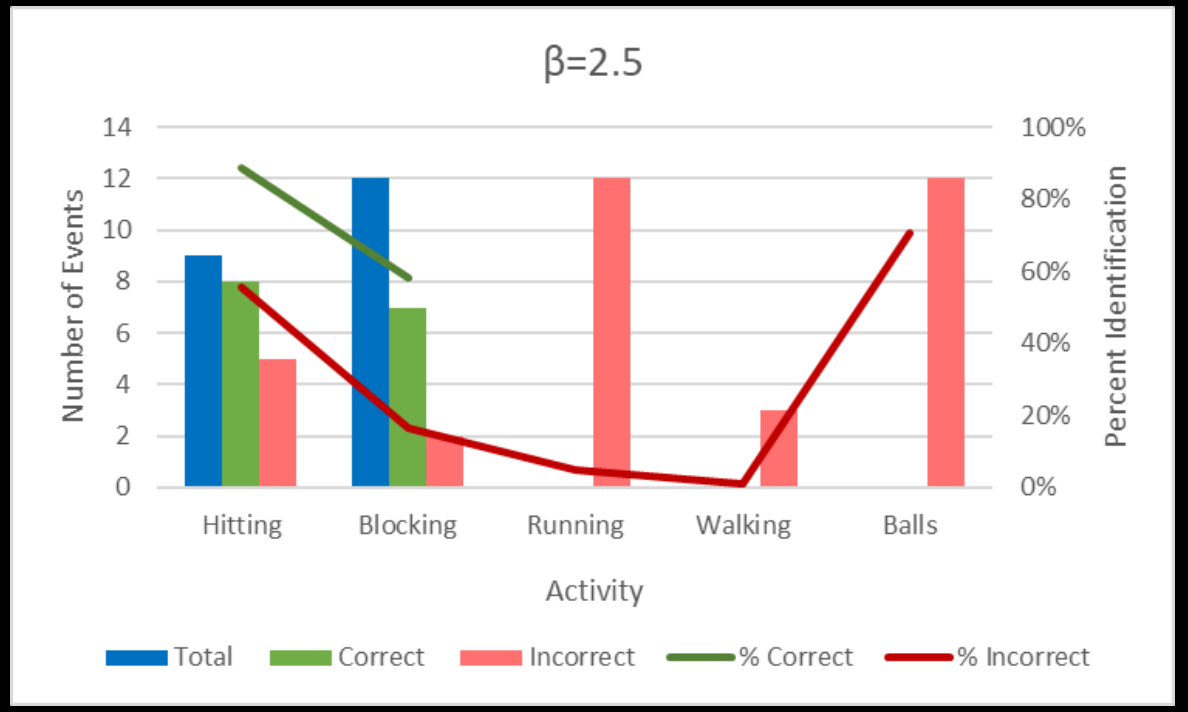


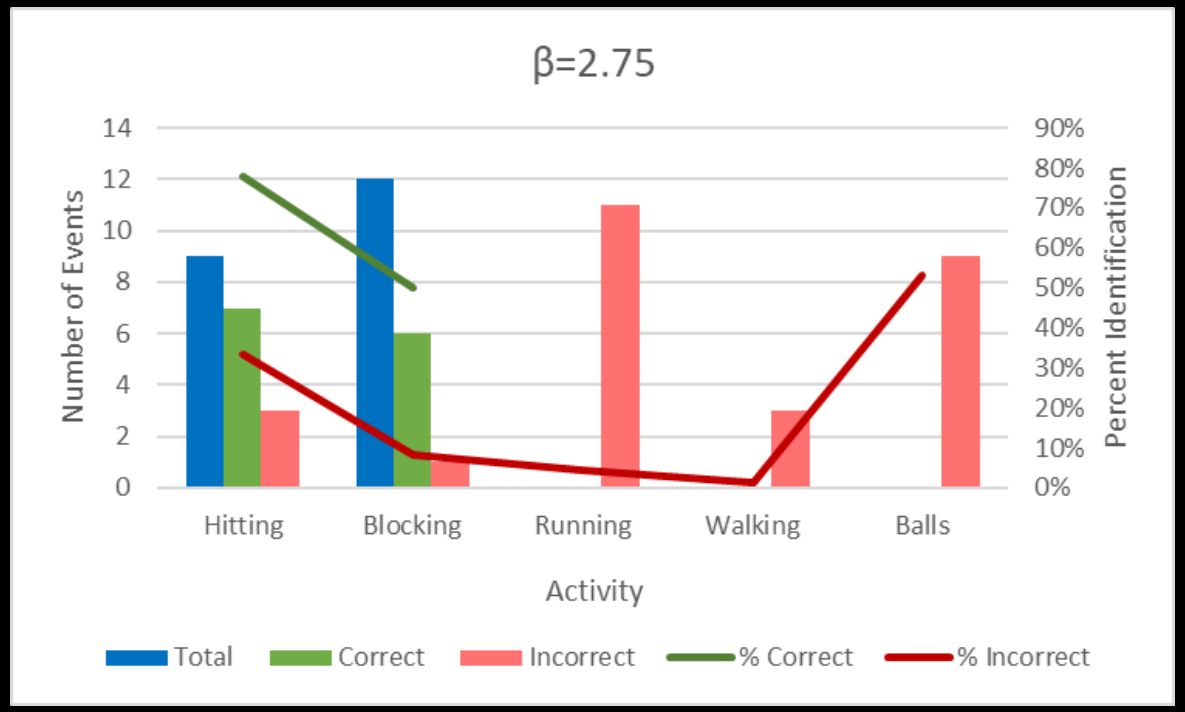
Steps to Refine

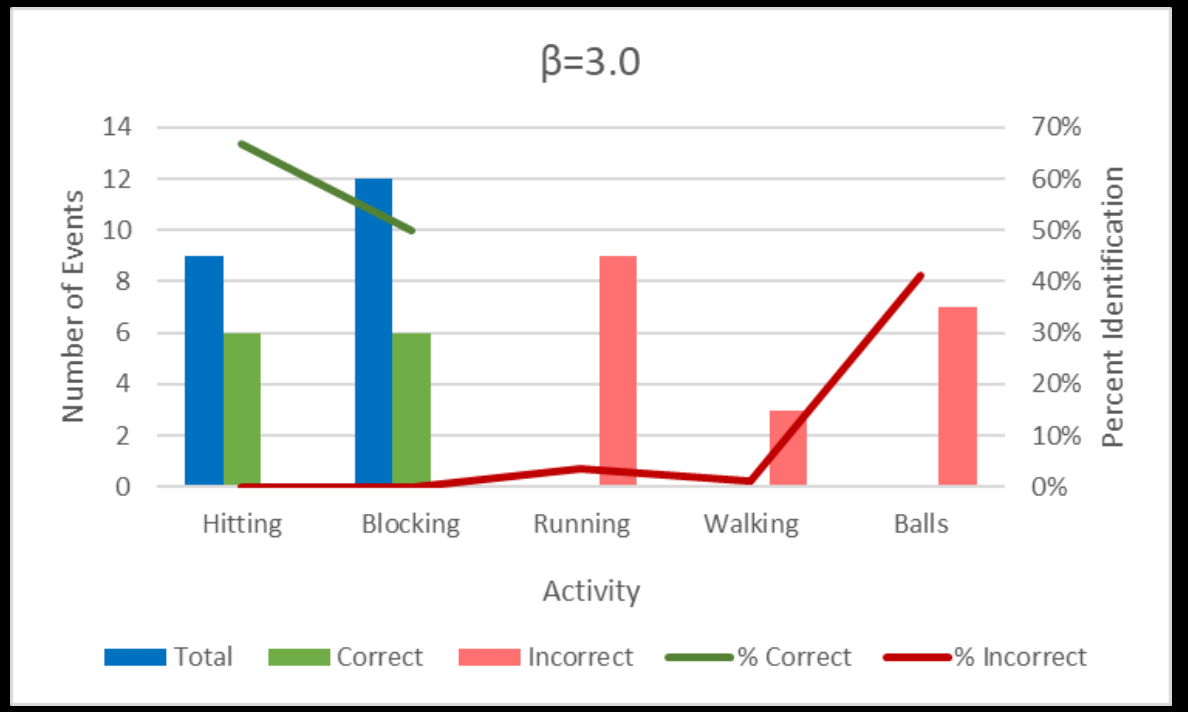
- Change minimum event separation
  - Use minimum time it takes to jump twice
- Change N (# of samples)
  - Increased N = Longer time interval
  - t=N/fs
  - Use smallest time interval that still detects jumps
- Change β
  - Larger β = Lower probability of false detection
  - Iterative process


Time Domain - hitting
Acceleration - g
1.2
1.1
1.0
0.9
0.8
0
10
20
30
40
50
60
Time -s
Raw Data
Unfiltered Jumps
Identified Jumps
Known Jumps

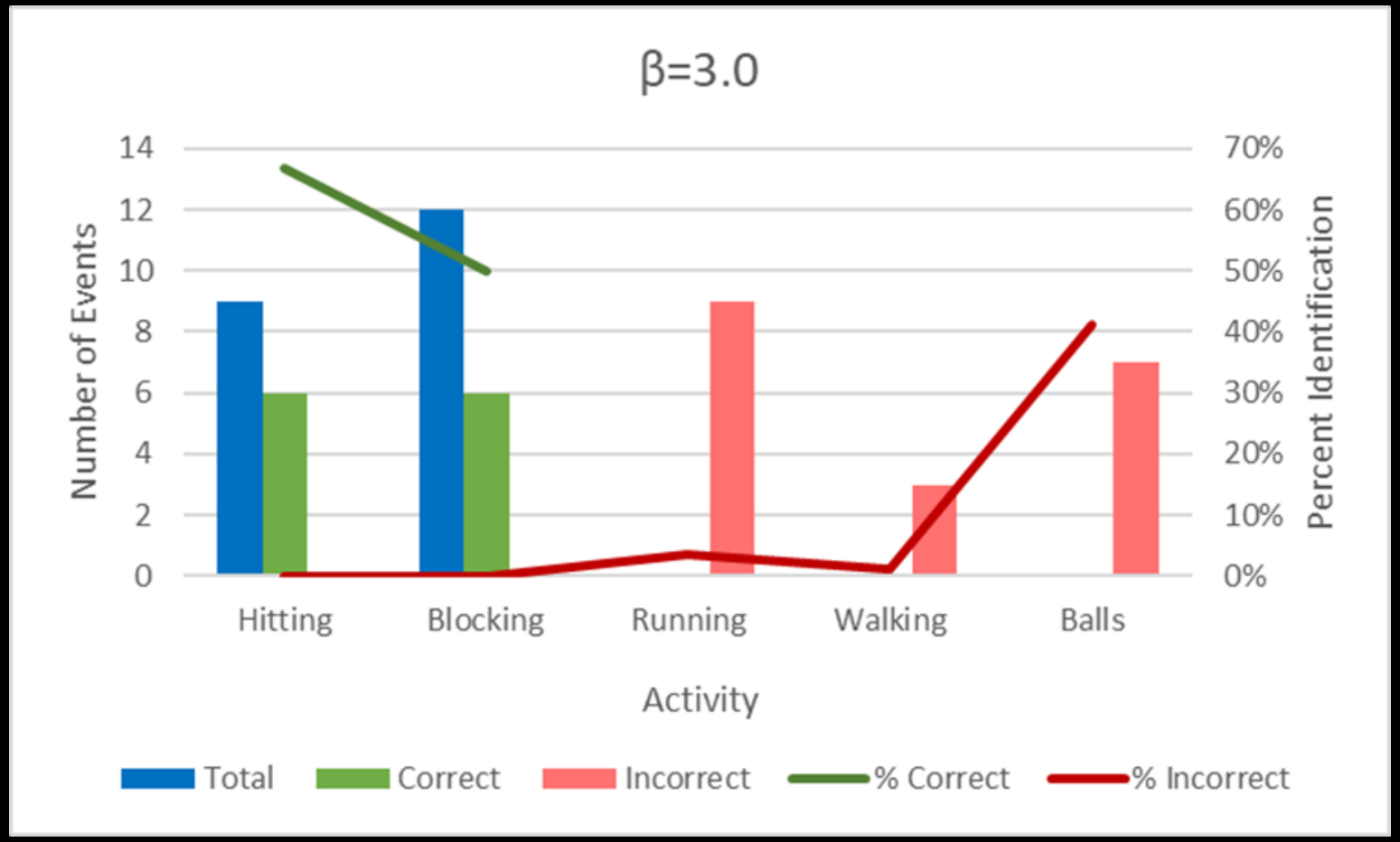

β=2.0
Number of Events
Percent Identification
Activity
Hitting
Blocking
Running
Walking
Balls
Total
Correct
Incorrect
% Correct
% Incorrect


β=2.5
Number of Events
Percent Identification
Activity
Hitting
Blocking
Running
Walking
Balls
Total
Correct
Incorrect
% Correct
% Incorrect

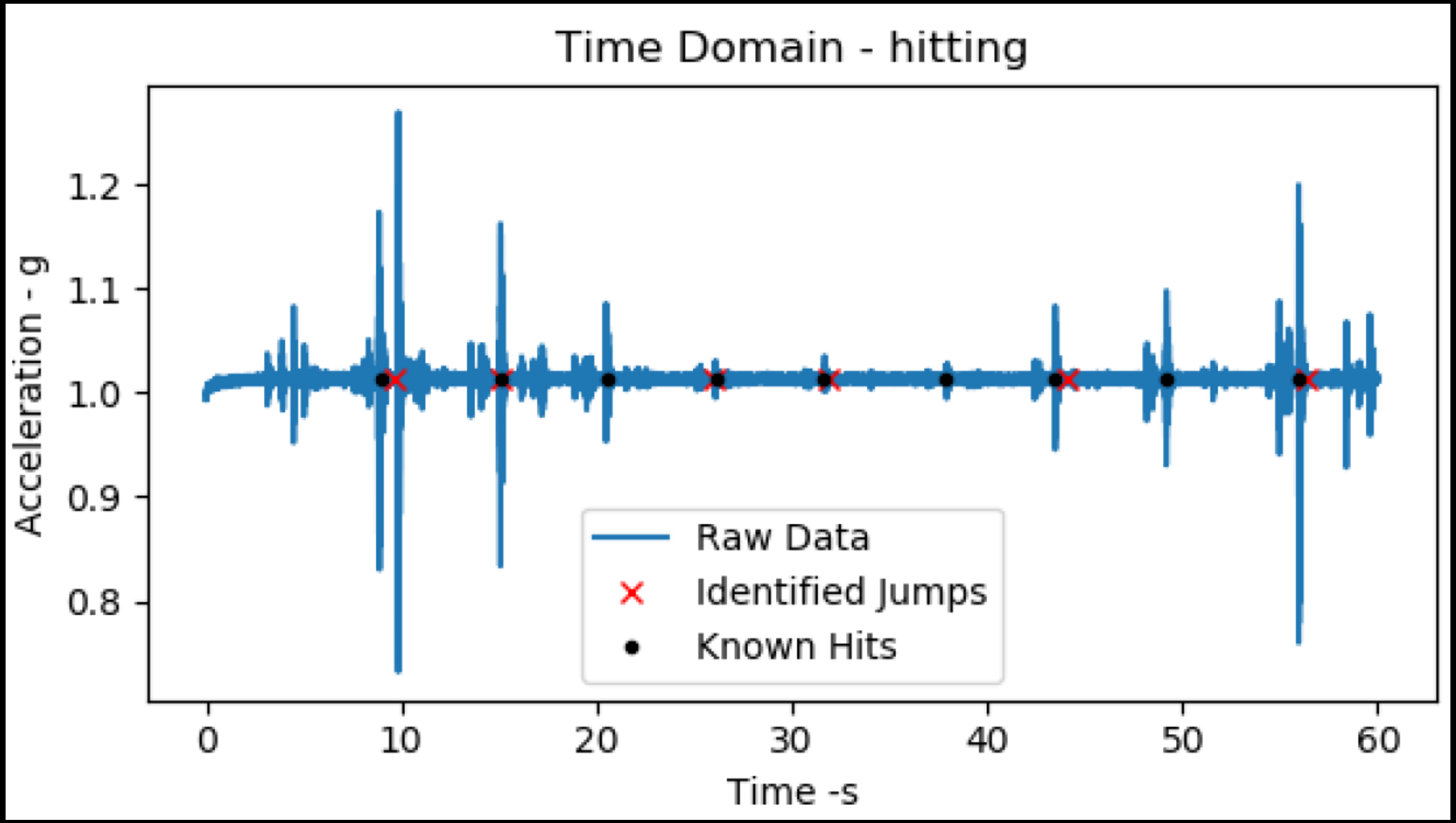

β=2.75
Number of Events
Percent Identification
Activity
Hitting
Blocking
Running
Walking
Balls
Total
Correct
Incorrect
% Correct
% Incorrect

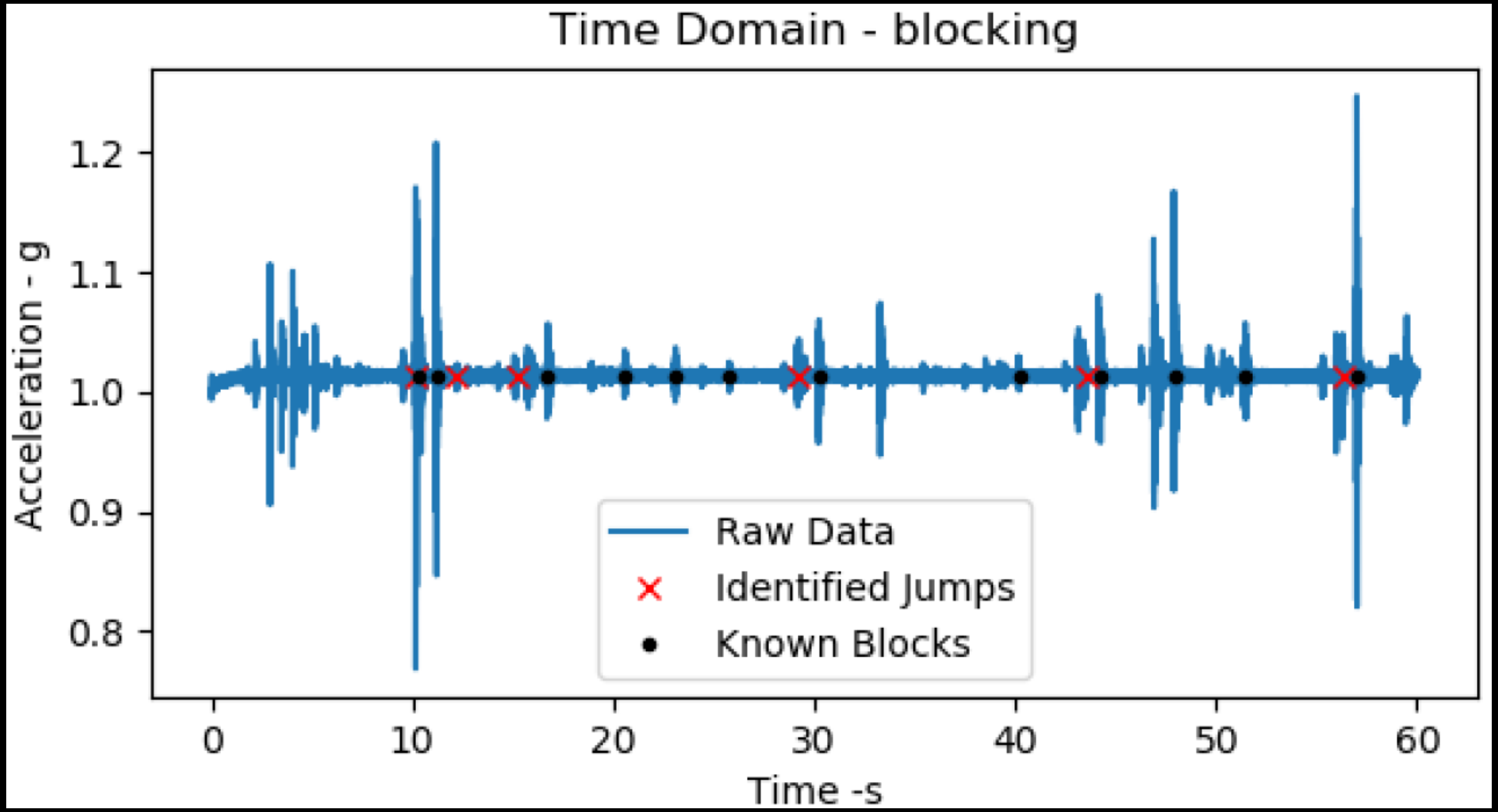

β=3.0
Number of Events
Percent Identification
Activity
Hitting
Blocking
Running
Walking
Balls
Total
Correct
Incorrect
% Correct
% Incorrect

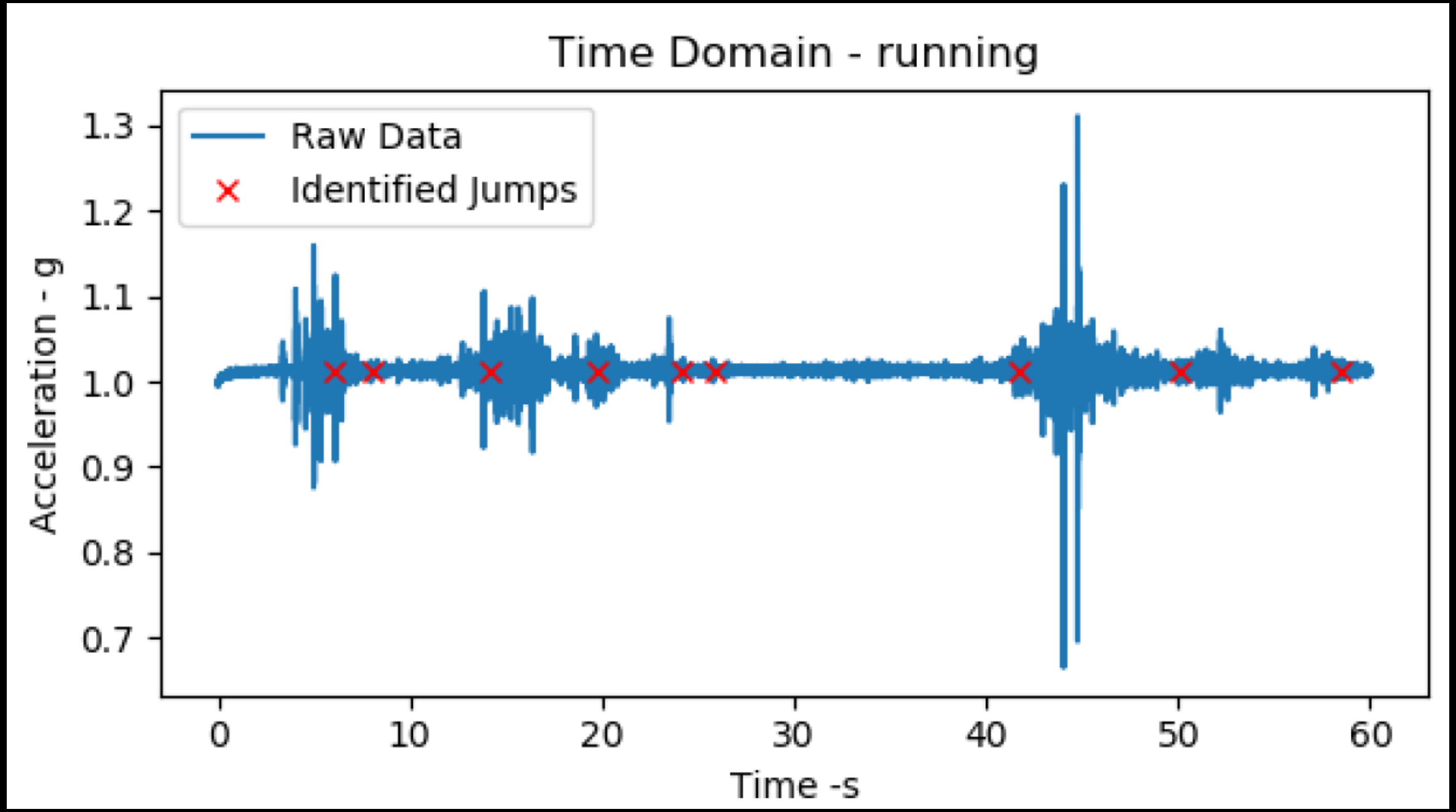
Final Parameters

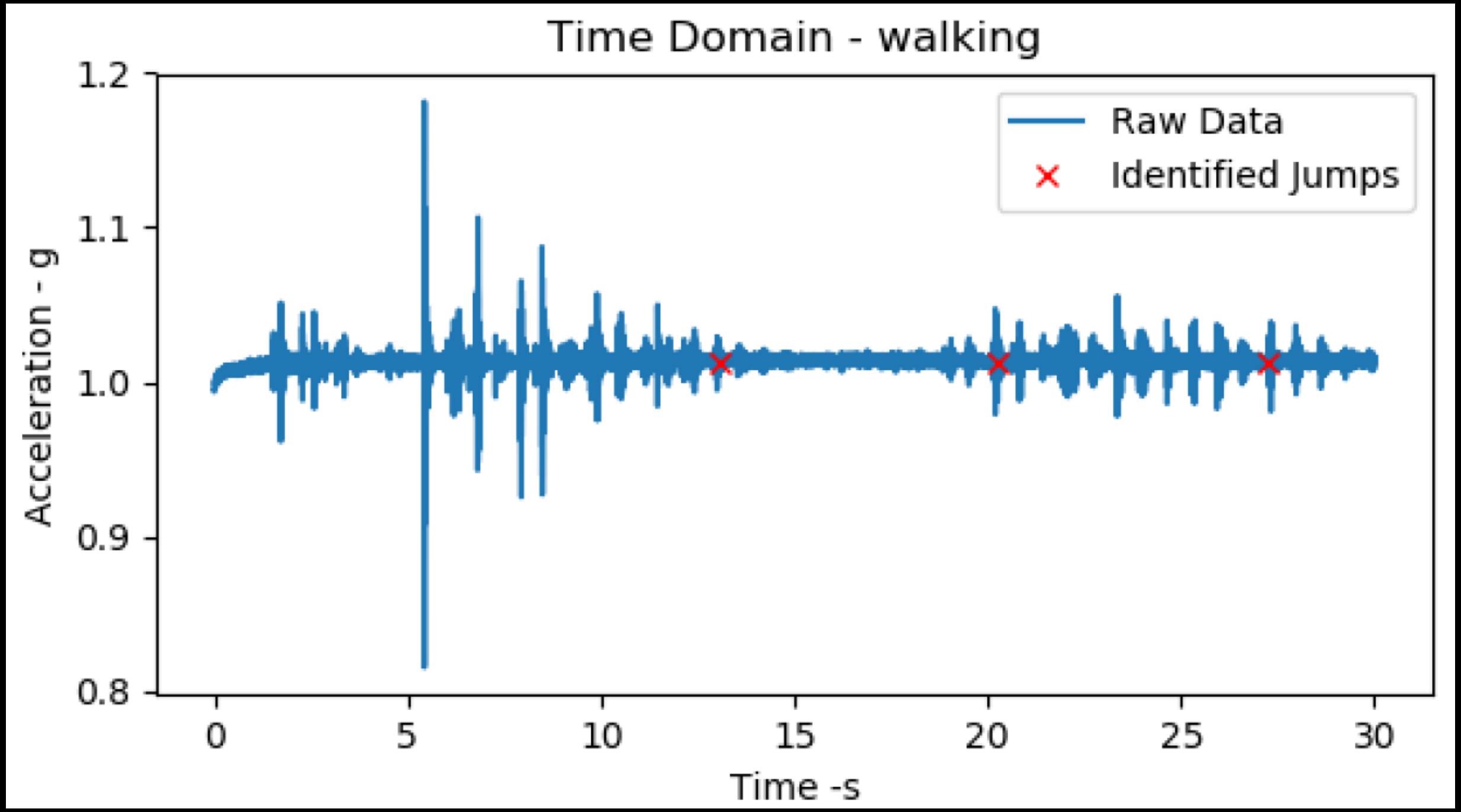


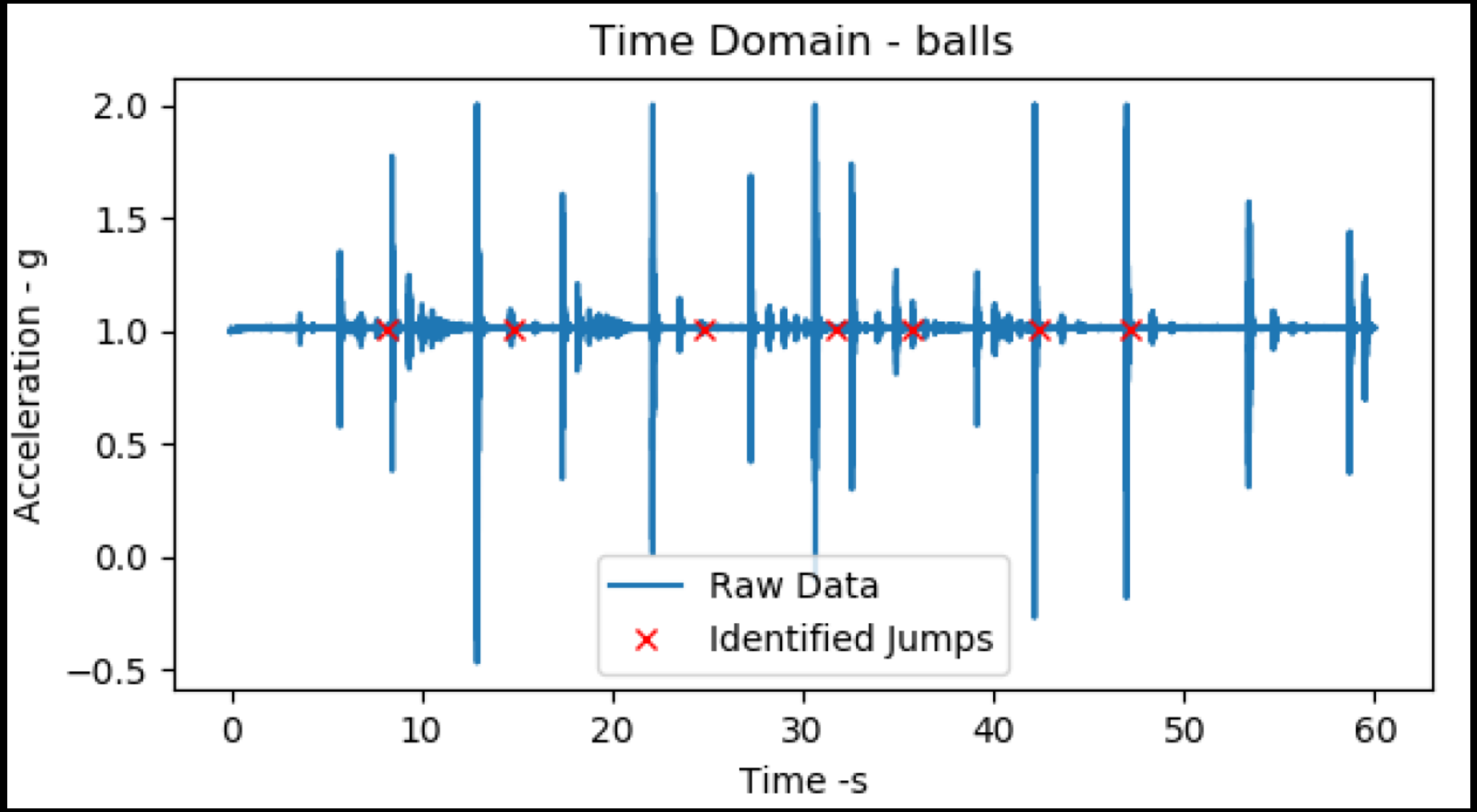
- β =3
- N=200
- Sep=1.5 sec
- Bands (Hz): 130-140, 150-160, 170-180

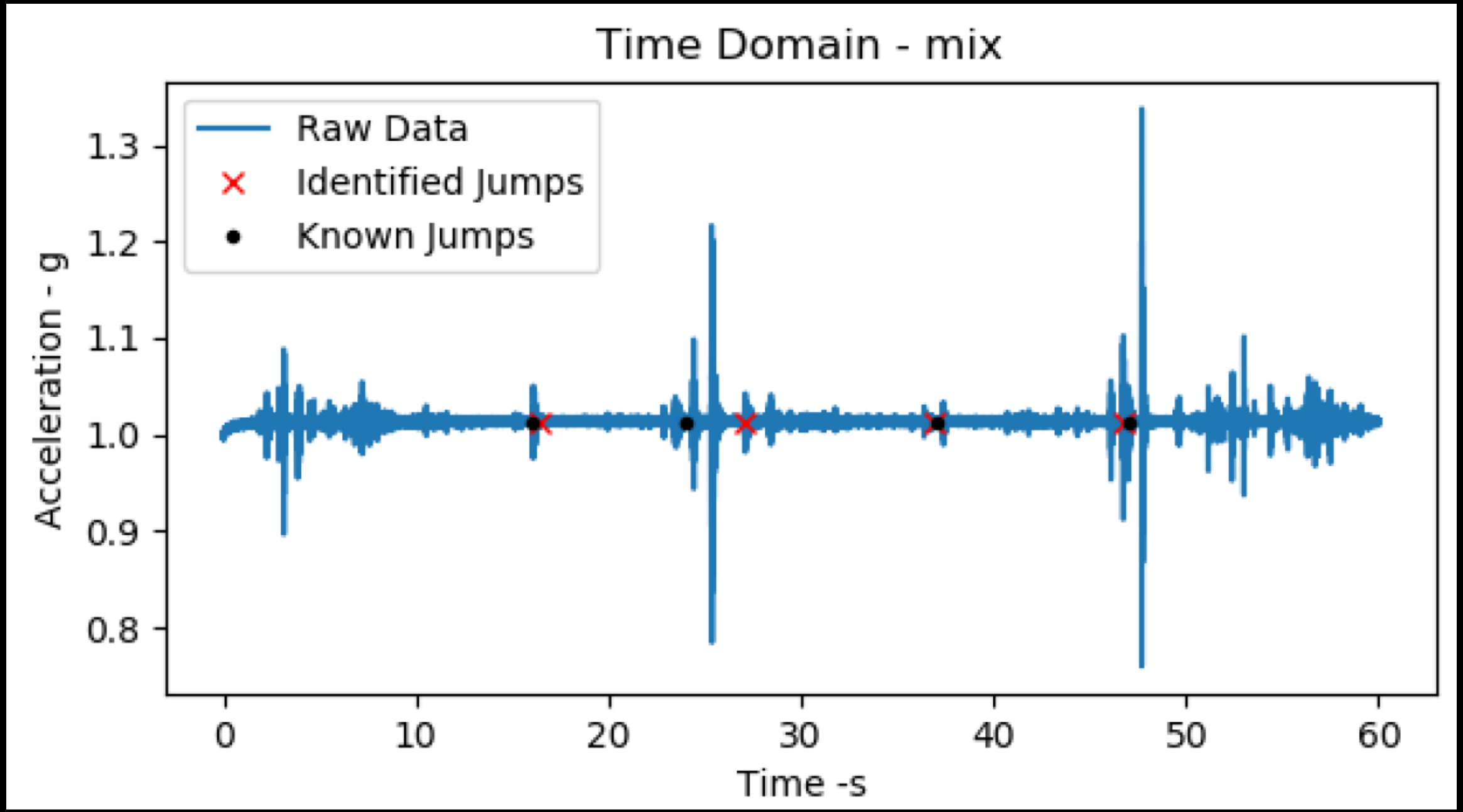

Time Domain - hitting
Acceleration - g
1.2
1.1
1.0
0.9
0.8
0
10
20
30
40
50
60
Time -s
Raw Data
Identified Jumps
Known Hits


Time Domain - blocking
Acceleration - g
1.2
1.1
1.0
0.9
0.8
0
10
20
30
40
50
60
Time -s
Raw Data
Identified Jumps
Known Blocks


Time Domain - running
Raw Data
Identified Jumps
Acceleration - g
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0
10
20
30
40
50
60
Time -s


Time Domain - walking
Raw Data
Identified Jumps
Acceleration - g
Time -s
1.2
1.1
1.0
0.9
0.8
0
5
10
15
20
25
30


Time Domain - balls
Acceleration - g
2.0
1.5
1.0
0.5
0.0
−0.5
0
10
20
30
40
50
60
Time -s
Raw Data
Identified Jumps


Time Domain - mix
Raw Data
Identified Jumps
Known Jumps
Acceleration - g
1.3
1.2
1.1
1.0
0.9
0.8
0
10
20
30
40
50
60
Time -s

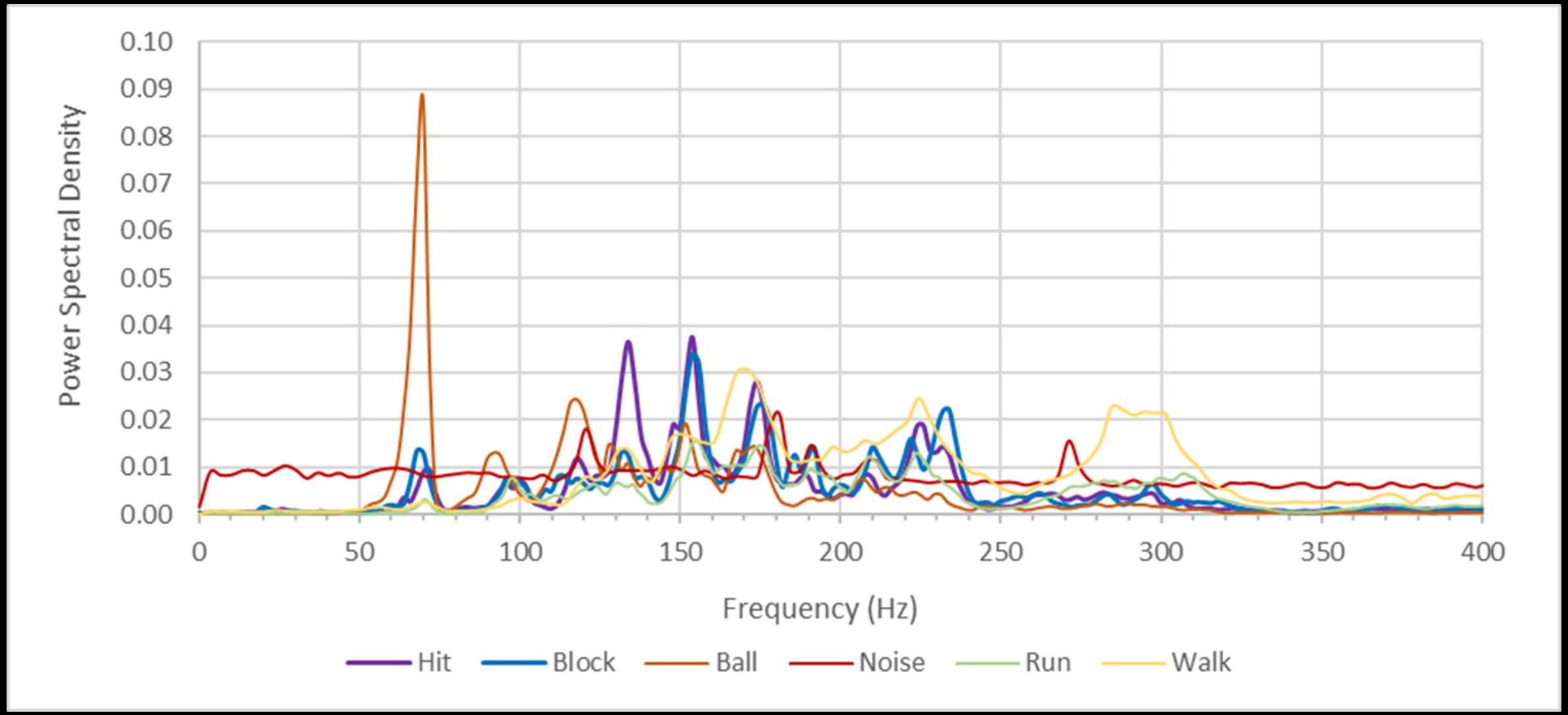
Possible Improvements

- More data collection
  - Jumping data to further refine which PSD bands to use
  - More balanced datasets for balls and running
  - Mixed datasets to see how well this performs in practice
- Further refinement of parameters
- Try different data collection set-ups
  - Different flooring
  - Different sensor location

Conclusion

- Acceptable jump detection with one person active
- Most likely to misidentify balls hitting the floor or running
- Has not been tested with concurrent events (multiple people)
- More improvements needed before this would serve as a viable alternative to available jump detection devices

Questions?


Power Spectral Density
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
50
100
150
200
250
300
350
400
Frequency (Hz)
Hit
Block
Ball
Noise
Run
Walk