BIOMECHANICAL PRINCIPLES AND MEASUREMENT TECHNIQUES

Problem Title	Comparison of methods for calculating vertical jump height in sport

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Learning Outcome(s)	
1	Describe the principles behind calculating jump height from impulse and from flight time
2	Apply the impulse-momentum relationship and relevant equation of motion separately to calculate jump height from net impulse and from flight time
3	Explain the potential limitations of each approach and their implications for the accuracy of the calculation.

Concepts / Competencies expected to engage with	● Impulse-momentum relationship ● Equations of motion (linear system, constant accel)

Course Level	Second-year undergraduate

This problem involves data analysis	**Yes**	No	Maybe

Approximate Length	2 hrs

Class/ Group Size	~20 students in groups of 3-4.

Useful References	Linthorne, N (2001). 'Analysis of standing vertical jumps using a force platform'. *Am J Phys* 69(11). Knudson, D. (2007). *Fundamentals of Biomechanics (2nd. ed)*. Springer, pp. 115-117, 147-148.

Mode of Instruction	In person (could be adapted to run online using breakout rooms and shared documents)

The Scenario:

In a coach education seminar, the volleyball coach from a nearby club team learns that the standing vertical jump for maximum height is a valuable test to assess athletic performance and to monitor athletes returning to full fitness after injury. She approaches you, as a local sport scientist, and offers you the contract to perform pre-season testing on the club's 1st team athletes. You advise that a force platform offers the ability to measure jump height in a controlled environment, and it is agreed that the force platform facilities at your local University will be used for the testing. Each athlete is instructed to stand on the force platform and do a counter-movement vertical jump, aiming to jump as high as possible and keeping their hands on their hips throughout the movement. Vertical ground reaction force (GRFv) data are recorded at 1000 samples per second during the complete movement. Three trials are collected per athlete, and the data for each trial are provided to you in an Excel spreadsheet. Here are the data from one athlete.

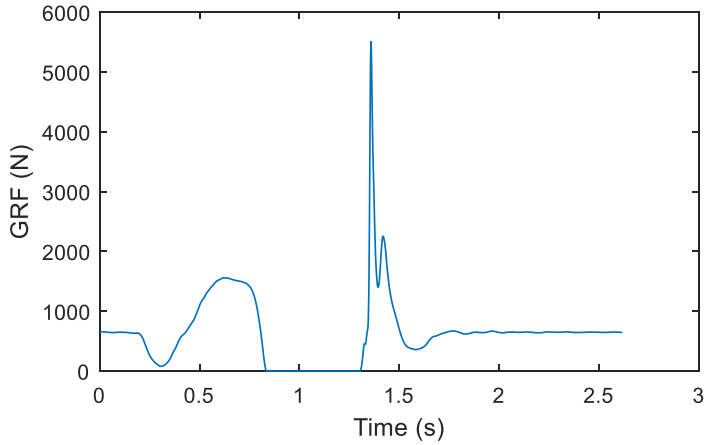

Figure 1: Vertical ground reaction force recorded during a standing counter-movement vertical jump

The Questions:

1. Use these data to calculate the athlete's mean jump height using two different methods:
    a. from their flight time
    b. from their vertical ground reaction impulse
2. Consider the limitations and assumptions of each of these methods. Which of your two calculated jump heights (1a and 1b) are you going to report to the club, and why?
3. You are training a junior sports scientist to conduct vertical jump height assessments using force platforms. Given the assumptions you identified in Q2 for each method, what instructions are you going to give them to ensure that the jump heights calculated from their data are as accurate as possible? Consider both calculation methods separately in your answer.
4. You are asked to test the same athletes again later in the season to identify whether their maximum jump height has changed. Will you use the same method as at pre-season or a different method, and why?

Expected Outcome:

The students will work in groups of ~3. Each student will analyse the data from one 'trial' (GRFv data from a CMJ) in Excel, and their calculated jump heights will be averaged to return the group's reported jump height for each method (if there are some groups of 4 then data from 4 trials can be provided and averaged). The calculation methods and the answers to the questions will be discussed within the small group, and a written answer sheet will be produced by the group (this can be uploaded to a shared class folder if working online). A group spokesperson will be nominated to present in the whole class discussion at the end of the session when invited to contribute. At the end of the session, the learning objectives will be revisited and the students asked to evaluate the extent to which they have been achieved. If there is time, students can be asked to suggest how the coach might use the results of the jump height testing.

To answer Q1, the students will need to be able to use basic Excel functions and their knowledge of the relevant equations of motion to calculate jump height from flight time and from numerical integration of GRFv data. The answer sheet can contain prompts to each stage of the calculation if needed, as appropriate for the cohort (e.g. a prompt to calculate and enter answers for impulse, momentum and vertical velocity at take-off when using the impulse-momentum method). To answer Q2-4, the students will need to consider the assumptions made in calculating jump height using each of these methods. They will need to think about how athlete technique is likely to deviate from these assumptions, and how these deviations can be reduced experimentally (e.g. by ensuring the athlete is stationary on the force platform before/after the jump when using the impulse-momentum method; by cueing the athlete to extend the legs fully in the air when using the flight time method). To answer Q4 they will additionally need to consider the purpose of the second assessment, i.e. identifying change.

Guided Questions (Hints):

- What are possible methods of estimating jump height? Which of these methods require only GRFv?
- Can you describe the phases of the counter-movement jump that are evident in Figure 1? Can you identify the flight phase?
- Can you plot your GRFv data?
- Prompting questions related to the calculation of jump height from impulse:
    - Can you describe how impulse relates to take-off momentum/velocity?
    - How does velocity at take-off relate to jump height?
    - Which of the equations we've covered are relevant here?
    - Would you expect the impulse method to overestimate or underestimate jump height, and why?
    - What assumptions does the impulse method rely on?
    - How might you design your data collection session or cue your athlete to minimise the deviation from these assumptions?
    - How would your calculation be affected if the athlete [landed with their knees flexed/did not stand stationary on the force platform/etc.]?
- Prompting questions related to the calculation of jump height from flight time:
    - What is the vertical velocity of the athlete at the instant they reach the maximum height of the jump?
    - Can you describe how flight time relates to jump height?
    - Which of the equations we've covered are relevant here?
    - Would you expect the flight time method to overestimate or underestimate jump height, and why?
    - What assumptions does the flight time method rely on?
    - How might you design your data collection session or cue your athlete to minimise the deviation from these assumptions?
    - How would your calculation be affected if the athlete [landed with their knees flexed/did not stand stationary on the force platform/etc.]?
- Why do these two methods give you different answers?