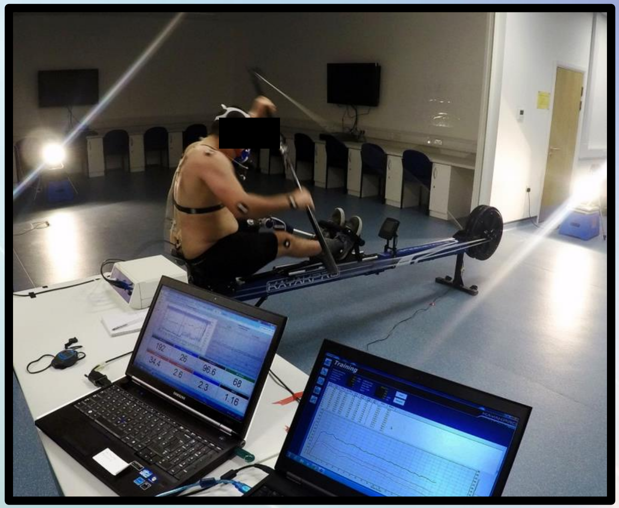


The Contribution of a Lower-limb Prosthesis on Paracanoeing Performance: A Case Study

Dr Bryce Dyer, Shelley Ellis & Dr Andrew Callaway
Bournemouth University, UK

Introduction

- Within the Paracanoeing discipline, it is important to ensure appropriate control is achieved by a paddler with a disability such as lower-limb absence.
- However, Paracanoeing has only seen circa 2 peer-reviewed studies to date.
- There is a lack of information or case studies available to help inform practitioners and academics within the sport.

Lower-limb Absence Related Typical Issues

- Prosthetic limb static fit.
- Prosthetic limb dynamic fit.
- Residual limb comfort *when under race specific conditions*.
- A ‘trial and error’ approach has typically been used for kayak set up.
- The main goal has emphasised comfort over performance.
- Whiting and Varette (2012) proposed necessary contact points in order to have full control over a kayak. These include the lumbar back, gluteal region, *hips, thighs, knees and toes*.

Study Aims

Through a case study approach, gain an understanding of the kinematic impact to a Paracanoeist when paddling with the use of a prostheses.

Put simply, beginning to address the question:

Is use of a prosthetic limb important when kayaking at race pace

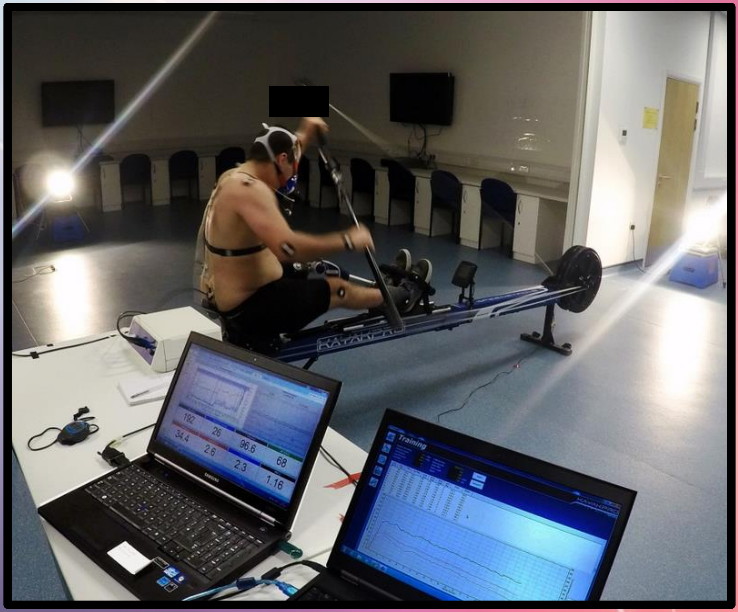
?

Methods (1)

A single canoeist/kayaker acted as the basis of this case study:

They were:

- A 30 year old male (height: 1.73m, weight: 86.5kg).
- A recreational-level kayaker (with four years of kayaking experience).
- Possessed a uni-lateral transfemoral amputation.
- The participant utilised their own current walking prostheses.
- A KayakPro ergometer was used.



Methods (2)

Experiment Design:

- The participant completed several 200m* maximal efforts (both with and without their prosthesis).
- A test familiarisation took place prior to the formal tests (to get used to the test equipment) as well as an additional 5 minute warm up.
- Two testing sessions (separated by a gap of two weeks) were undertaken.
- Each session comprised four *maximum* effort 200m* paddles performed on a kayak ergometer.
- Each 200 m time-trial was separated by a minimum rest period of 45 minutes.

*The 200m distance was selected as it represented the athlete's Paracanoe class competition distance and the approximated rest periods between trials replicated the competition structure used at the Rio Paralympic Games.

Methods (3)

Experiment Design:

- Each time-trial involved the measurement of: *stroke-rate (spm), stroke-length (m), time* (secs) and *power output (W)*.
- In addition, a 2D camera system (Fujifilm HS10 at 210Hz) focused on visible markers positioned on the hip and knee (then recorded in the sagittal and frontal plane).
- Markers were located on the lateral aspect of the distal end of the femur (of the residual limb) and the greater trochanter (and visible from the frontal and sagittal view cameras).

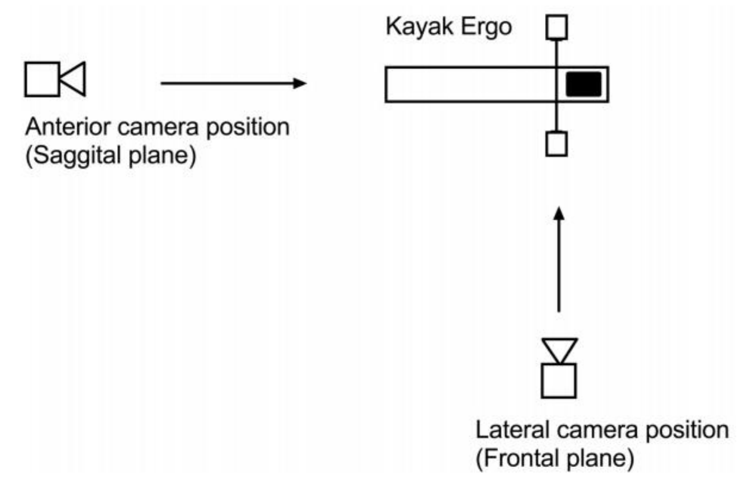


Figure 1. Overhead view of the experimental setup showing planes.

Methods (4)

Experiment Design:

- The biomechanical measures were taken from the video cameras by tracking retro-reflective markers using Quintic v26.
- The tracking of the markers from side and front view were digitized to allow traces of the markers movements to be observed (Figure 2).

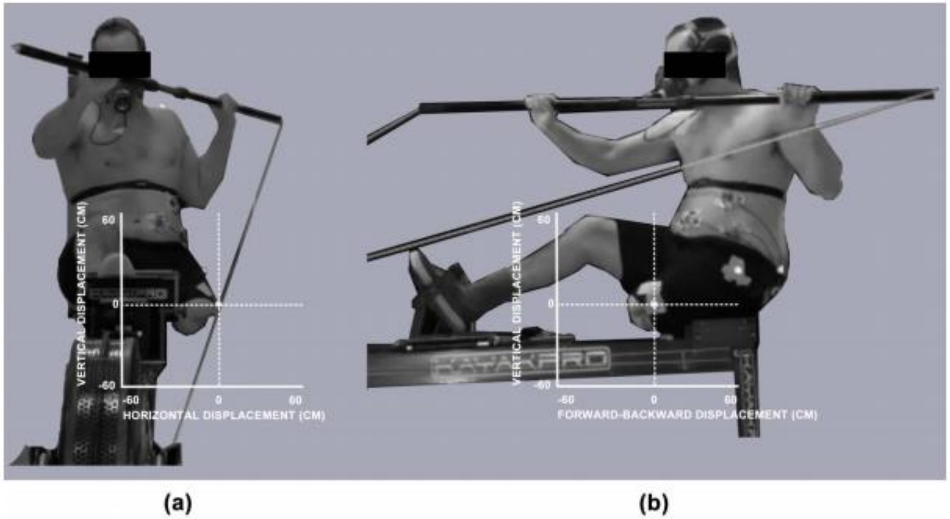


Figure 2. Representation of marker placement and displacement of marker in terms of anterior (a) and lateral (b) camera views.

Results (1)

<u>**Performance**</u>

- When the prosthetic limb <u>*was removed*</u>, there were significant differences found with:
  - stroke rate (*P*=0.003)
  - stroke speed (*P*=0.0001)
  - stroke length (*P*=0.002) (and on both sides – despite the unilaterality of limb absence)
  - power output (*P*=0.0001)

- The four trials of *with* or *without* prostheses saw no significant differences in these metrics (thereby demonstrating no signs of fatigue).

Results (2a)

Video Analysis

- Sagittal and frontal video analysis demonstrated the residual limb movements when paddling and indicated where support would be required to improve the kayak's control.

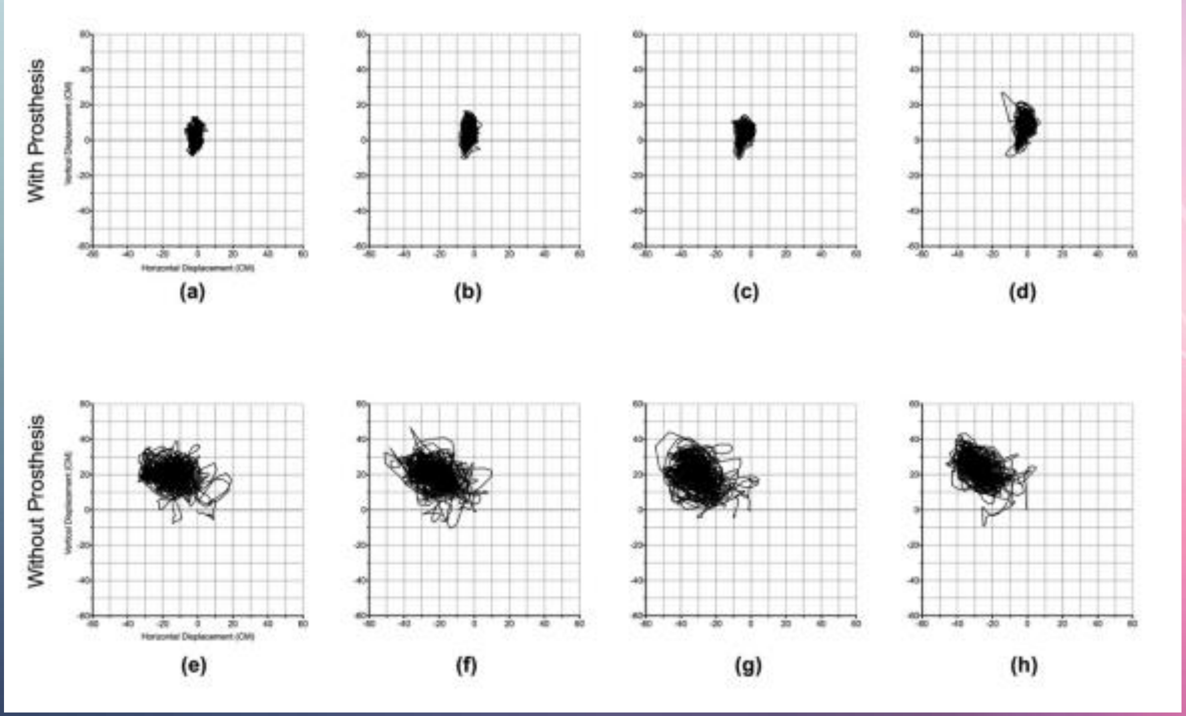
- Note: without a prostheses, the left hand side stroke reductions were as large as 69mm (!).

- It is recommended that those with lower-limb absence wishing to paddle a kayak competitively utilise the use of a prostheses designed for the kayaking environment that supports the residual limb at both the upper and inner thigh and the distal end.

Results (2b)

Video Analysis (anterior view of the knee of the amputated lower-limb)

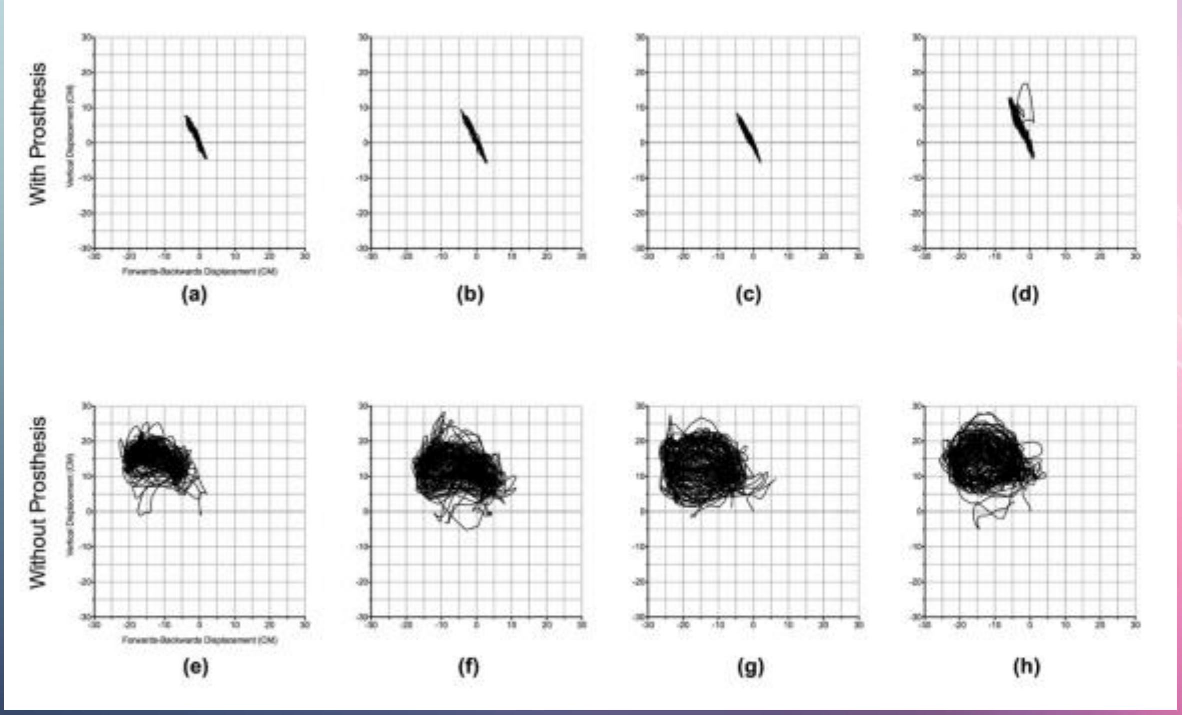
- With the prosthesis fitted, the graphs (a-d) show a predominately vertical movement of the knee.



Results (2c)

Video Analysis (lateral view of the knee of the amputated lower-limb)

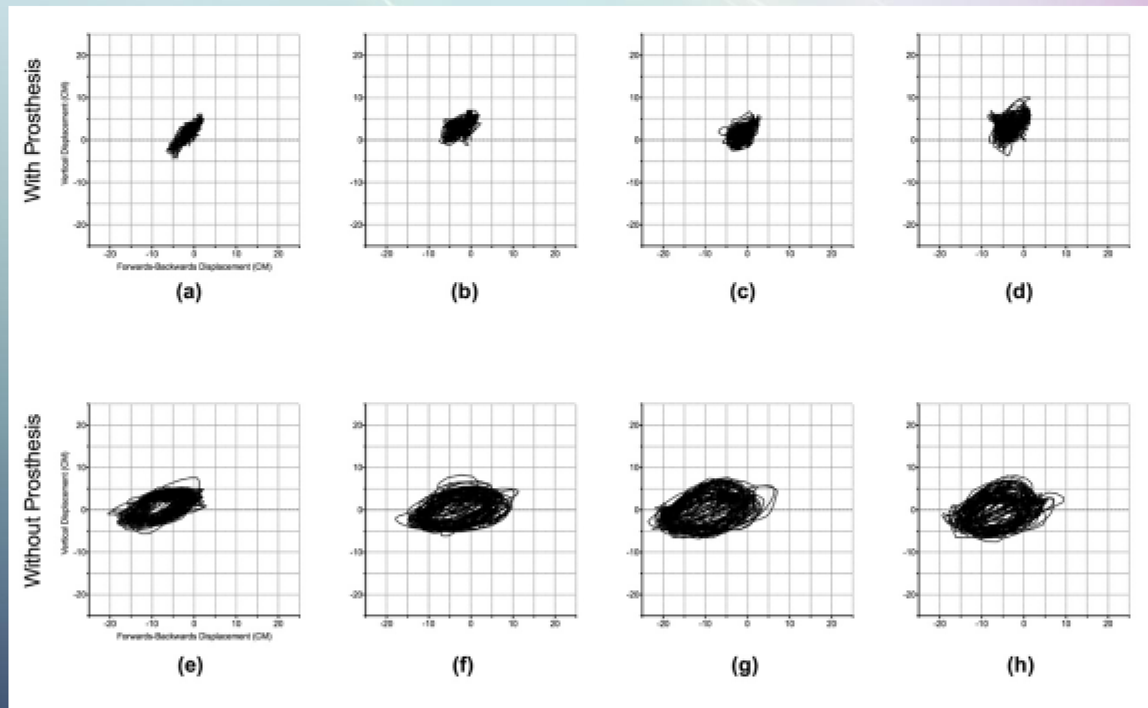
- With the prosthesis fitted, the graphs (a-d) show a predominately vertical movement of the knee.



Results (2d)

Video Analysis (Frontal view of the hip of the amputated lower-limb)

- With the prosthesis fitted, the graphs (a-d) show a predominately vertical movement of the knee.



Summary: With no prosthesis (Figure e-h) the movement tends to be towards the centreline of the body and upwards towards the abdominals.

Key Discussion Points (1)

- The experiment protocol used for this study was appropriate (in that no performance degradation was identified).
- To maintain overall kayak velocity (and thus having the same race time), the participant would have had to adapt their paddling technique if they chose to utilise a prosthetic limb or not.
- Prosthetic limbs for Paracanoiests should not save weight at the expense of providing appropriate levels of support to the paddler.

Key Discussion Points (2)

- The recreational participant did obtain a stroke rate similar to that of elite paddlers, but the lack of rhythm in the 'without prosthesis' condition suggests that the applied stroke was significantly ineffective.

- The paddler would need to compensate for this with an increased stroke rate (which is unlikely).

- The prosthetic limb provides essential paddler stabilisation.

- In this particular case study, the detected limb segment movements suggest :
  - support is required on the inner & upper thigh (to act as a brace).
  - support at the distal end of the stump (to stop slippage in the seat)*.

*ICF guidelines at the time of this study was missing recommendation of this vital distal end support

Conclusions

- The lack of a prosthetic limb support resulted in the paddler losing contact at their hip, thigh, knee and toe on the left leg. As a result they would have less control over their kayak.
- Prosthetic limb design for Paracanoiests should not save weight at the expense of providing appropriate levels of support to the paddler.
- A tailored and personalised solution will likely be necessary.

Outcomes for Practitioners

- This paper is the first study to investigate both biomechanical and assistive technology-related issues in the new Paralympic Games sport of Paracanoeing.
- A prosthetic limb (that is designed specifically for the kayaking environment) is recommended when Paracanoeing with limb absence to maximize efficient propulsion.
- Use of an ergometer and multiple 2D cameras provides practitioners the ability to optimize both the comfort and fit of a prosthetic limb.
- Use of an ergometer and multiple 2D cameras provides both athletes and practitioners the ability to optimise the points of human contact within a kayak to ensure comfort and control.
- Such outcomes can then be field tested using such methods as Dyer (2018).

…..so is the Paracanoeing prostheses important ?

- This first case study suggests YES.

- However, this also means that the implications of the specific design of prostheses will have potentially a positive or negative impact on sporting performance too.

and one more thing…..

Field Testing Innovative Prosthetic Solutions

- Use of the Stroke Index (SI= average velocity X stroke length) may be a means to determining a field-based indicator of overall paddling efficiency of new technology.

- SI has been validated for swimming (Costill et al. 1985) and stand-up paddleboarding* (Dyer, 2018).

*Dyer, B.T.J., 2018. A Proposed Field Assessment Method for Stand-up Paddle Board Technology. *Journal of Engineering and Applied Sciences*, *13*(8), pp.2020-2025.

Areas For Future Exploration

- The study of more paddlers is warranted to investigate functional diversity between a larger sample.

- Optimisation of prosthesis weight/points of contact to:
  - maintain direction
  - maximise craft acceleration off the start.

- Explore different points of internal paddler to craft contact to maximise physiological power transfer across the whole event length.

- Limb *absence* does not mean limb *replacement.*

FIN

Dr Bryce Dyer, Bournemouth University, UK.
brdyer@bournemouth.ac.uk