# OPTIMAL CONTROL FOR MAXIMIZING ROBUST TWISTING TECHNIQUES ON TRAMPOLINE

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## Abstract

In this research, a multiple-shooting algorithm has been used to find optimal arm movements maximizing the number of twists in a straight backward somersault. Optimal movements have been disturbed 100 times and interpolated to assess the robustness of the optimal movement. The optimization process has shown that full shoulder motion techniques generated about one more twist than abduction/adduction only techniques. A quarter of the optimal techniques were found to be robust.

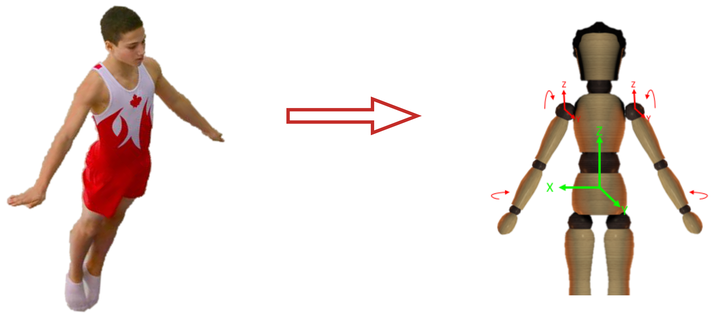
**Mots clés:** Trampoline, direct multiple shooting, aerial twists, twisting somersaults, model simulation

## Introduction

- Aerial twisting techniques have gained coaches interest since the flight time is part of the score in trampoline.
- As these techniques are not intuitive, computer simulation is an interesting tool to explore a wider variety of techniques without any risk of injury.
- Until now, simulations of twisting somersaults have mainly been realized with 1-degree-of-freedom (DoF) arm actuation: abduction-adduction [1].
- Optimal techniques found with computer simulations might be infinitely precise, whereas athletes can not be that precise.

**Objective:** Explore full shoulder motion techniques to find innovative optimal techniques.
Test the robustness of these techniques.

## Method



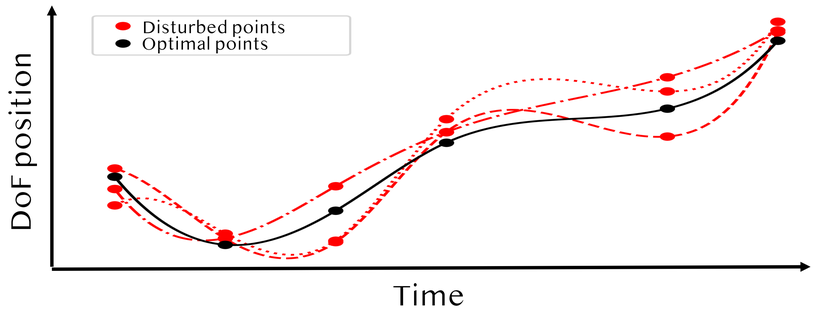
3D Model composed of 10 DoF allow to find techniques with computer simulation.

Multiple-shooting algorithm is used to maximize twist rotation according to the dynamics equation:

$$\tau = M(q)\ddot{q} + N(q,\dot{q}) + G(q)$$

Subject to constraints such as finishing the skill with around one backward somersault, arms above the head and less than 15° of tilt.

A multi-start approach (n = 3720) allows to find multiple optimal solutions.

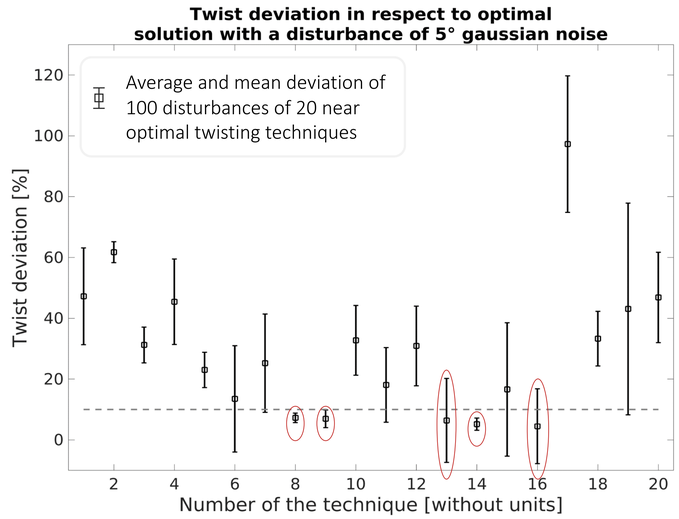



A hundred gaussian disturbances are added to the optimal solutions DoF positions to simulate the athletes lack of precision compared to computer simulation. The number of twists generated by disturbed movements is then approximated by interpolating quartic splines. If the average number of twist interpolated is deviating of less than 10% from the number of twists of the optimal soltion, the technique is considered to be robust.

## Results et Discussion

One of the 20 optimal 3D techniques.

Two DoF per arm techniques generated about 4½ twists, whereas one DoF per arm techniques generated 3½ twists.




Twenty optimal techniques were found and five out of them were found to be robust.

## Future work

Mesurements on high level athletes will allow to include realistic contact twist velocities and test these robust optimal solutions.

## References

1. Yeadon (1999) Int Symp of Biomech in Sports