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► **To cite this version:**

Thibault Marsan, Mickael Barbat, Élodie Dancerel-Bourlon, Bruno Watier. Turning judges ranking into biomechanical parameters for cheerleading. 2024. hal-04738046

**HAL Id: hal-04738046**

**<https://hal.science/hal-04738046v1>**

Preprint submitted on 15 Oct 2024

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# Turning judges ranking into biomechanical parameters for cheerleading

Thibault Marsan\*

LAAS-CNRS, Toulouse, France

Mickael Barbat

LAAS-CNRS, Toulouse, France

Élodie Dancerel-Bourlon

LAAS-CNRS, Toulouse, France

Bruno Watier

LAAS-CNRS, Toulouse, France

CNRS-AIST, JRL IRL, Tsukuba, Japon

\*Corresponding author. Email: [tmarsan@laas.fr](mailto:tmarsan@laas.fr)

**Keywords:** judge ranking; stunts; Xsens Suit

## 1. Introduction

Cheerleading is a sport able to participate in the Olympics since 2021 but it has not been selected yet. The partner stunts performed during the cheerleading routines showcase strength, balance, and coordination (Laëtitia Flahaut, 2023). They begin with a base (the person providing support) holding the flyer (the person being lifted). In the preparation phase, the flyer makes two squats, the second one being the greater to generate impulse, then is raised by the base to finish in its hands. The objective of the flyer is to be sheathed and immobile during this static phase.

Cheerleading, like many other sports is evaluated by judges during competitions. The judges have grids to rate the routine based on the creativity, the technical difficulty, and the correct execution of the stunts, which makes it a subjective rating. However, the grids differ between the competitions. Some studies focused on rationalizing the cheerleading rating (Synytsya et al., 2024). There were however few studies on this topic, which made it difficult to objectively rate the cheerleading performance. Biomechanics could help in this matter to define objective parameters that would be linked to performance, and to the ranking made by the judges.

Furthermore, there was no study associated with cheerleading biomechanical performance, it could then be interesting, for coaches and athletes, to be able to determine biomechanical parameters involved in the performance during classical stunts in cheerleading. Therefore, the objective of the study was to find relations between biomechanical parameters such as kinematics or center of mass displacement and cheerleading performance, based on judges ranking. This study focused on two stunts: the walk-to-hands and the toss-to-hands. Those stunts were selected with coaches of the Wolves Toulouse Cheerleading team.

We hypothesized that the kinematics of the lower limbs during the preparation phase before the jump of the flyer, as well as the displacement of the center of mass during the static phase, while the flyer is in the hands of the base, were related to performance based on ranking by cheerleading judges.

## 2. Methods

### 2.1 Obtaining biomechanical data

Four participants, two flyers and two bases, formed four duos. The two flyers were with the following characteristics: age 25 and 28, mass 42 kg and 53 kg, height 142 cm 159 cm. And the two bases were with the following characteristics: age 25 and 29, mass 86 kg and 88 kg, height 171 cm 180 cm.

The Xsens Suit© was used to obtain the 3D kinematics of the flyer by 17 interconnected IMUs with a frequency of 240Hz. The 3D angles and the whole-body centre of mass were computed and provided through the MVN Analyze© software (Figure 1). Five successful toss-to-hand and five walk-to-hand were recorded for each duo.

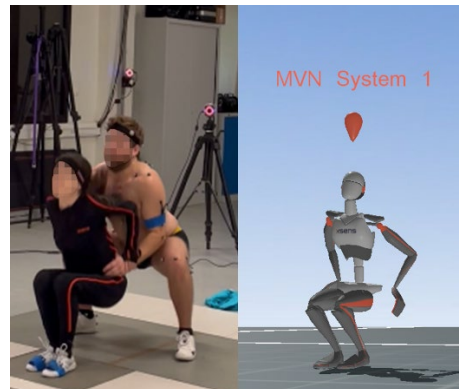


Figure 1 Experimental setup on the left with the Xsens suit on the flyer during a toss-to-hands, and the corresponding avatar in MVN Analyze on the right.

Credit: Thibault Marsan

### 2.2 Obtaining judges ranking

Two cheerleading coaches, with five years of national experience within the Wolves Toulouse Cheerleading team, were recruited for this study. One of them had a previous experience as a cheerleading judge for two years at a regional level. We defined, with their help, criterion on which they would base their ranking. We agreed to use only one grade, from one to ten, as it is done in competition but we based it on the success of the flyer motion only. One being the lower grade corresponding to the flyer feet that were not caught at the height of the shoulder of the base. Ten being the higher grade corresponding to the fact that the flyer feet were caught by the base with their arms extended. The judges reviewed the videos of the stunts and gave a rating for each stunt.

### 2.3 Data processing

Since the Xsens Suit was validated for the lower limbs but not for whole body (Nijmeijer et al., 2023), only

the flexion of the hip, knee, and ankle were considered. The first and second squat during the preparation phase were manually identified for the two stunts and the joint angles values were selected when the flyer was flexed at their lowest height.

The range of motion of the displacement of the centre of mass in the horizontal plane, along the anteroposterior axis ( $CoM_x$ ), along the mediolateral axis ( $CoM_y$ ), and the maximal velocity of the centre of mass in the horizontal plane ( $V_{CoM_H}$ ) were computed during the static phase.

Those data were correlated with the grades given by the cheerleading coaches. The two coaches were considered separately first, then the mean grade of the two coaches was used.

### 3. Results and discussion

No correlation was found for the joint angles, whether individually or with the mean of the grades. This suggested that, even collectively, the precise positioning of the joints, quantified by the flexion angles in the sagittal plane of the lower limbs, did not determine the scores a stunt receives. The relationship between joint angles and scores could be more complex than a direct correlation could capture. For example, there might be certain combinations of angles or sequences of movements that are favored, which simple correlation analysis would not reveal.

**Table 1.** *p-values for the correlation between the grades of each coach and the mean of the coaches' grades and the parameters of the centre of mass.*  
credit: Thibault Marsan

	Coach 1		Coach 2		Mean Coach	
	TTH	WTH	TTH	WTH	TTH	WTH
$CoM_x$	<0,01	<0,01	0,13	<0,01	0,03	<0,01
$CoM_y$	0,16	<0,01	0,45*	<0,01	0,31*	<0,01
$V_{CoM_H}$	0,01	<0,01	0,20*	<0,01	0,09	<0,01

\* means p-value<0.05

Correlations were found between the grades of the second coach, the displacement of the centre of mass along the mediolateral axis ( $CoM_y$ ) and the velocity of the centre of mass in the horizontal plane ( $V_{CoM_H}$ ). The mean grade of the two coaches also correlated with the  $CoM_y$ . This illustrated the bias that subjective ranking can exist in cheerleading judges (Synytsya et al., 2024). Finding correlations between the center of mass displacement and judges' grades might suggest that how the cheerleader's mass is balanced and moved throughout a stunt played a role in how the stunt was judged. This could be because displacements of the centre of mass were directly linked to the stability, balance, and control exhibited during a performance. The videos of only four duos were analysed and some weak correlations have been found. It could then be interesting to obtain the ranking of other judges, to limit the subjective bias.

### 4. Conclusions

Our study was the first to investigate the correlation between the kinematics of the cheerleading practioners and the grades given by the judges.

One main result was the absence of correlation with joint angles and the presence of some with center of mass displacement and it highlighted the complex interplay between technical precision and artistic expression in cheerleading. Furthermore, these findings highlighted the subjective nature of cheerleading evaluations. This subjectivity may not necessarily be a flaw but a reflection of cheerleading's rich blend of athleticism and performance art, requiring a nuanced approach to training, performance, and evaluation.

These insights offered valuable guidance for coaches and athletes in focusing their training efforts and for the development of more comprehensive and fair judging criteria that balance objective biomechanical metrics with the inherent subjectivity of artistic performance.

### Acknowledgements

The authors would like to thank the Wolves cheerleading team athletes and coaches for their involvement in this study.

### Funding

No funding must be reported for this study.

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Received date:05/04/2024

Accepted date: 28/06/2024

Published date: XX/XX/2024

Volume: 1

Publication year: 2024