TITELSEITE

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# Biomechanics of a toss to hands in cheer sport

Biomechanics can generally be understood as “the study of the movement of living things using the science of mechanics” (Knudson, 2007). This broad field of interest can be sectioned in many different ways, Richard & Kullmer (2019) distinguish three domains: orthopaedic biomechanics, ergonomics/occupational physiology and sports biomechanics. This work is located within sports biomechanics, which includes analysis and optimisation of sport-specific movement technique, development, analysis, and optimization of methodological exercises, development and optimization of sports apparel and equipment, as well as prevention of injuries due to overtraining and unphysiological loads and stresses (Richard & Kullmer, 2019). The current study targets the analysis of sport-specific (here: cheerleading) movement (here: toss to hands) technique.

## Why is this necessary?

Apprehending sports technique might seem like a nerdy topic; however, it becomes quite relevant when approaching competitive sports. Athletes suffer higher injury risks when they train at a higher level. Meeusen & Borms (1992) concluded for gymnastics that with a higher level of performance, the difficulty of elements as well as the time spent practicing in the gym will increase evidently. They also refer to studies highlighting a “positive correlation between the time spent in the gym and chronic injuries” and “intensity as well as duration of training were identified as related to injury” (Meeusen & Borms, 1992). This very likely accounts for cheerleading, too. To lower these injury risks, appropriate technique and prehabilitation measures are substantial for (elite) athletes. But technique and prehabilitation both essentially require knowledge of the sport and its elements, especially for a sport as quickly advancing and developing as cheerleading.  
As currently most (if not all) elements in cheerleading are taught as have been taught, meaning a coach will only teach what and how they learned themselves, this study can be considered fundamental research in the field of cheerleading.

## The history of cheerleading / What is cheer sport?

With the rise of intercollegiate football games in the mid-1800s fans started chanting fight songs to cheer on their college team (Varsity Spirit, 2014; Grindstaff, 2015; International Cheer Union [ICU], 2018; USA Cheer, 2022). In November 1989 Johnny Campbell, a student at the University of Minnesota, was the first to enter the field organize the crowd in their chant – the first cheerleader (Varsity Spirit, 2014; International Cheer Union [ICU], 2018; USA Cheer, 2022). Until the early 1920s cheerleading grew to an all-male extracurricular activity, offered by high schools and colleges across the US (Varsity Spirit, 2014; Grindstaff, 2015; International Cheer Union [ICU], 2018; USA Cheer, 2022). In 1923 the first woman was allowed to join a cheerleading squad; however, it took 20 more years for female cheerleaders to not be an exception in cheer teams (Varsity Spirit, 2014; Grindstaff, 2015; International Cheer Union [ICU], 2018; USA Cheer, 2022). In these (and following) centuries cheerleaders expanded their skill set by adding tumbling and acrobatics to their routines, as well as props such as megaphones, signs, and poms (Varsity Spirit, 2014; International Cheer Union [ICU], 2018; USA Cheer, 2022). By now, cheerleading is predominantly female (90?% in Germany in 2021[[1]](#footnote-1)). Cheer sport is recognized by the International Olympic Committee (International Olympic Committee, 2022) and contains everything between side-line cheers and highly competitive athleticism. Today, cheersport unites all kind of disciplines that originate from organised groups cheering on certain sports teams. This includes but is not limited to:

* sideline teams: slow/static acrobatics paired with claps, motions, and chants, usually affiliated with a football team.
* competitive teams: practicing with the main goal of skill acquisition and competing at championships; usually more fast paced routines and higher difficulty acrobatics and tumbling.
* dance teams: highest variety of disciplines from hip hop to pom dance with simple, smoothly executed tumbling and acrobatic elements.

This study refers for the most part to competitive cheerleading. Competitive Cheerleading is categorized by skill level (ranging from zero to seven), age (peewees, juniors, and seniors) and team composition (female-only teams called all-girl teams and mixed teams with up to four or more male athletes called coed). The combination of level, age, and team composition defines the division under which the teams compete against each other.

## The toss to hands

The toss to hands is one of the most basic however fairly technically difficult stunts in coed stunting. Coed stunting usually refers to a male base with a female flyer, where the base lifts the flyer into the air and catches them afterwards on their own.   
A toss to hands is a mounting element where the base tosses the flyer so they will land in the base’s hands, standing. Therefore, the base stands behind the flyer with their hands holding onto the flyer’s hips. The flyers’ hands grab the wrists of the base from above. The flyer then performs a squat jump, pushing off the base’s wrists. The base follows the movement of the flyer and extends their arms above their head before releasing the flyer’s hips. The base then catches the flyers feet, completing the movement by standing with the flyer’s feet in their hands at shoulder height.

## Current state of research?

# Methods

* Overall procedure
  + Vicon, external markers
  + Why not simulink shape identification?

## Participants

In total 14 athletes (7 female, 7 male) participated in the underlying study. The participants’ ages reach from 22 to 35 (M=27.21, SD=4.14) years. All participants have been pursuing cheer sport for a total of 4 to 16 (M=8.64, SD=2.98) years, and have been familiar with the skill for 1.5 to 11 (M=8.64, SD=3.04) years. The participants joined in already existing pairs or have been paired up by the instructor when joining individually. For further information about the participants age and experience separated by position see **Table 1** below.

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Table 1

Participants.

|  |  |  |  |
| --- | --- | --- | --- |
| **Position** | Mean age [years] | Cheerleading experience [years] | Toss to hands experience [years] |
| **Flyer** | 25.14 +-3.18 | 9.00 +-3.30 | 6.07 +- 2.96 |
| **Base** | 29.29 +-3.69 | 8.29 +- 3.30 | 7.50 +- 2.31 |

Participation was attained through a public call by the instructor shared with contacts and social media Each participant gave informed consent before data acquisition started.

## Marker Placement

A total number of 65 markers is used in each trial: 33 markers on the base, 32 markers on the flyer. The goal of the marker selection is to enable a full-body data acquisition, recording the major joints (shoulder, hip, knee, and ankle) and still enable the grips needed to perform the skill without forcing the subjects to adjust their usual technique. Generally, the marker set used is based on the plug-in gait marker set as shared by vicon nexus[[2]](#footnote-2). To enable an environment where the athletes feel comfortable to perform their skill as they always do and do not feel the need to change anything only to avoid covering or ripping off markers, some marker positions (WRA/B, RASI, LASI and HEE) needed to be altered.

### Upper Body

The upper body marker placements of flyer and base are almost identical. Both received the same number of markers (17), laid out in **Table 2** below. The markers C07V, CLAV, STRN, and T10V represent the torso with an additional marker RBAK on the right shoulder blade for improved side recognition. The markers SHO, UPA, ELB, WRA, WRB, and FIN represent the upper extremity and are attached to both arms of every subject. With exception of the wrist markers all upper body markers are attached following the Vicon Nexus Plug-in Gait guide[[3]](#footnote-3). On the flyers’ wrists the marker placements are also following the mentioned guide. As the flyer grabs the bases wrists to push themselves off during the movement, the bases’ wrists can not be marked the usual way. Therefore, the bases’ wrist markers are placed further cranial, mostly halfway between wrist and elbow. While marker placing the arms rested in a neutral position, forearm bones remaining parallel. WRA and WRB are attached to the outer crests of the respective forearm bones.

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Table 2

Upper Body Markers.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Marker** | **Placement** | **Bilateral** | **Unilateral** | **Medial** |
| C07V | Vertebrae C7 |  |  | X |
| CLAV | Clavicula |  |  | X |
| STRN | Sternum |  |  | X |
| T10V | Vertebrae T10 |  |  | X |
| RBAK | Right back/shoulder blade |  | X |  |
| SHO | Shoulder | X |  |  |
| UPA | Upper arm | X |  |  |
| ELB | Elbow | X |  |  |
| WRA | Wrist A | X |  |  |
| WRB | Wrist B | X |  |  |
| FIN |  | X |  |  |

Sources: Wu et al. (2005),

### Lower Body

While mostly similar, the lower body marker placements differ a little bit more between flyer and bases: Flyer received 15 markers, while bases received 16, as displayed in **Table 3** below. The markers PSI and ASI (for bases) or ASIS (for flyer) represent the pelvis. The markers THI, KNE, TIB, ANK, HEE, and TOE represent the lower extremity. With exception of the flyers anterior hip marker, all markers are placed bilaterally, mostly following the Vicon Nexus Plug-in Gait guide[[4]](#footnote-4). The anterior pelvic markers as well es the heel markers of the flyer need alterations to not disturb the movement during the data acquisition.

As the base must grab the flyer’s hips, the anterior superior iliac spine is covered by the base’s hands, therefore it was not possible to place the frontal hip markers regularly. Instead, one marker (APEL) is placed vertically aligned with the belly button, horizontally aligned with the pRASI/pLASI (potential RASI/LASI) position assuming the hip crest to be equally far away from the centre of the hip. RASI and LASI trajectories can later be approximately reconstructed by adding/subtracting half the distance between pRASI/pLASI onto/off the ASIS marker trajectory.

The common Plug-in Gait marker position of the heel marker does not interfere with the toss itself, however it does interfere with the catch of the toss, completing the skill “toss to hands”. Hence the actual markers are moved 7 cm cranially along the calf.

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Table 3

Lower Body Markers

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Marker** | **Placement** | **Bilateral** | **Unilateral** | **Medial** |
| ASI – Base only | Anterior Superior Iliac Spine | X |  |  |
| PSI – Base only | Posterior Superior Iliac Spine | X |  |  |
| APEL – Flyer only | Anterior Pelvis |  |  | X |
| THI | Thigh | X |  |  |
| KNE | Knee joint | X |  |  |
| TIB | Tibia | X |  |  |
| ANK | Ankle | X |  |  |
| HEE | Heel | X |  |  |
| TOE | Toe/foot | X |  |  |

Sources: Wu et al. (2002),

## Data Acquisition

A session of data acquisition starts with an introduction into the topic of the study, followed by verbal instructions of the upcoming task. All participants are informed about the procedures of data acquisition including video recording and their option to step back from the current trial at any time in verbal and written form. After signing for informed consent, the stunt pairs are given the opportunity to warm up their tosses, especially if they have not stunted together before. Then, the instructor attaches the markers to both athletes. With markers mounted the athletes are given ten minutes to do any warm-up they need to be able to perform 10 to 15 tosses. When warmed up, the athletes get into the starting position, as is depicted in figure XY. To enable better data processing the starting position, known as t-position, is performed in the beginning of every toss: Flyer and base face forward in the same direction, the base standing in line behind the flyer. Feet are up to shoulder width apart and arms elevated to shoulder height to the respective sides, palms facing downwards. After a sign from the instructor, they get into their set position for the toss to hands and perform A person drinking wine at a table with food

Description automatically generatedthe skill. This marks the end of one trial. The next trial starts when both athletes get back into their starting position. In case of markers falling off the timing is evaluated and repeated if necessary. Trials with markers falling off after completion of the tossing process do not need to be repeated.

Figure 1

Starting position of every trial.

## Judges recruitment

## Judges’ questions

# Results

## Quantitative results

## Qualitative results

# Discussion

* Combine quantitative and qualitative results

# Conclusion?

* Phrase qualities of a ‘good’ toss to hands

# Literature

1. CCVD statistik M/W? [↑](#footnote-ref-1)
2. Source? [↑](#footnote-ref-2)
3. Reference! [↑](#footnote-ref-3)
4. Reference! [↑](#footnote-ref-4)