BIOMECHANICAL ANALYSIS OF SCHWINGEN (SWISS WRESTLING) TO GAIN INSIGHTS INTO HEAD, NECK AND KNEE INJURY RISKS

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This research project aims to reduce incidences of injuries to the head, neck and knee in schwingen (Swiss wrestling) by means of biomechanical analysis. In this pilot study, kinematic and kinetic data were acquired during key manoeuvres in schwingen for the first time. Two professional athletes at Swiss national level in schwingen were performing the so-called Kurz, the Hüfter and the bridge in a simulated competitive setting. The peak vertical ground reaction force, acting on the back as the opponent was hitting the ground during the Hüfter, was measured to be 11500 N; while the peak vertical ground reaction force on the head during the bridge was 2360N, respectively. The knee flexion angle of the leading leg during the Kurz was 55°, with the total knee joint forces being 410N in the anterior-posterior direction and 400N in the medio-lateral direction, respectively. In comparison with reported cervical spine injury risks in American football and sumo wrestling, injury mechanisms at the level of the head, neck and knee in schwingen are likely a result of the applied forces from dynamic throws, in combination with extreme joint ranges of motion during fixed grips and defensive manoeuvres such as the bridge. An extended biomechanical analysis of the applied forces, moments and joint kinematics during schwingen is recommended to develop targeted injury prevention guidelines.

KEYWORDS: head and neck trauma, ground reaction forces, inverse dynamics, sports biomechanics, injury risk

INTRODUCTION: Schwingen is a type of wrestling that is popular in Switzerland, performed on sawdust without weight classes, categories or protective equipment. During a contest, the athletes are wearing short wrestling breeches that are designed to take hold at the belt and the hem (Fig. 1), with the goal to throw the competitor onto the ground in a supine position. Each bout lasts at least five minutes and ends when time runs out or when an athlete's back touches the ground completely or simultaneously at the middle of both shoulder blades. Most of the grips in schwingen are fixed and originally only a few throws were used. Today, around 100 different throws are described in wrestling manuals; yet, five throws remain most commonly trained and practiced, including the so-called Hüfter and the Kurz ("Technisches Regulativ of the Swiss Schwinger Association," 2008).

A wide range of injuries have been reported in schwingen, caused by the high contact physicality of the sport, lack of weight categories and lack of protective equipment (Maliachovas et al., 2018). In particular, the most commonly injured regions are the head and the knee, ranging in severity from minor headaches and ligament strains to severe spinal cord injuries and bone fractures (Maliachovas et al., 2018). The cervical spine is particularly susceptible to injury when the head strikes the ground or lying on the floor in a twisted position with the risk of extreme hyperflexion, hyperextension, lateral flexion, axial loading or rotational forces of the neck. Even though major damage to the spinal cord are infrequent, they present catastrophic events because functional recovery of the nervous system is poor.

Current training guidelines in schwingen are mostly based on the experience of the coach and not based on scientific evidence. As emphasised by Maliachovas et al. (2018), the underlying injury mechanisms need to be better defined in order to develop targeted training guidelines for successful injury prevention in schwingen. Here, biomechanical analysis plays a key role in the development of targeted training guidelines to protect the safety of athletes (Lorenzetti, Dayer, Plüss, & List, 2017; Schellenberg et al., 2017; Torg, Vegso, O'Neill, & Sennett, 1990). For example, the insights from biomechanical data on head and neck injuries

in American football tackles led to the implementation of rule changes with a subsequent dramatic decrease of reported injuries (Torg et al., 1990). Unfortunately, similar biomechanical data is currently missing in schwingen.
The goal of this pilot study is to gather biomechanical data during key manoeuvres in schwingen for gaining insights into head, neck and knee injury mechanisms. In particular, the following three key manoeuvres were focused on:

- *Kurz*: The Kurz is the most traditional and most popular throw, taught from an early age onwards. Thereby, the opponent is lifted off the ground with the back onto the leading knee. Both, attack and defence during the Kurz depend on the correct positioning of the legs and knees with respect to the opponent.
- *Hüfter*: The Hüfter is a similar throw to the Kurz. While the Kurz is mainly executed through muscular forces of the arms, the technique of the Hüfter focuses on the rotational moments in the hips and upper body to lift the opponent off the ground.
- *Brücke*: The bridge is a key defensive manoeuvre to avoid touch-down with the back, whereby the head and the feet are the only points of contact with the ground. The bridge is one of the first manoeuvres practiced with young athletes, and the importance of targeted neck and head muscular strengthening to avoid injury is emphasised in the technical manual of the Swiss wrestling association for youth (Altermatt et al., 2018).

METHODS: Data from optical motion capture and ground reaction forces were measured during simulated bouts between two professional athletes in schwingen (Fig. 1). Both subjects provided written informed consent to participate in this pilot. Participants were heavier than 99 kg and taller than 185 cm and about 22 years old. Both athletes had been competing in schwingen on a Swiss national level for several years.
A force plate (AMTI KMP, 600x900mm) and a Vicon optical motion capture system with 14 cameras were used for data acquisition. A 700x1000mm hole was mined into the sawdust, the force plate was mounted on a wooden board, concealed in a dust-proof envelope and placed at a depth of 400mm. A slippery textile was used to surround the side of force plate in order to reduce shunt forces within the sawdust. The standard plug-in-gait marker set was used. During the Kurz, the leading leg was placed on the force plate. During the Hüfter, the back of the opponent had to land on the force plate, while for the bridge, the head had to land on the force plate, respectively. At least two trials of the Kurz, the Hüfter and the bridge were recorded at 200Hz. Inverse dynamic analysis was conducted to derive the knee flexion angle and forces acting on the knee joint during the Kurz based on the acquired data. A moving average filter was used for the force data.

Figure 1: Measurement set-up (top) and optical markers on head, shoulder and upper body (bottom)

RESULTS: For the Kurz, the knee flexion angle of the leading leg was 55°. The forces acting on the knee joint of the leading leg were 410N in the anterior-posterior direction and 400N in the medio-lateral direction, respectively. The knee flexion moment was estimated to be around 160 Nm based on the measured data. The highest vertical ground reaction forces were measured during the Hüfter when the opponent was hitting the ground with the back, reaching 11500 N (Table 1). Here, the duration of the peak force was 0.03s. Entering the bridge in the position where the head is touching the ground and the feet are still in the air, the force was measured to be 2050N. During the bridge, the peak vertical ground reaction force that was acting on the head was measured to be 2360N (Table 1). The duration of the peak force during the bridge was 0.03s.

Table 1. Maximum ground reaction peak forces during schwingen.

Movement	Force Fz [N]
Kurz /lift (Leg)	2670
Hüfter/throw (Back, landing)	11500
Brücke/bridge (Head)	2360

DISCUSSION: Without existing weight categories or protective equipment in schwingen, the development of technical skills based on targeted training guidelines is crucial to protect the safety of athletes. The peak vertical ground rection force, measured on the landing back during the Hüfter, was more than four times larger than the peak force on the head during the bridge. While the bridge is a defensive manoeuvre and not a dynamic throw, the results from this study confirm that a large amount of weight is supported on the head (i.e. 2-3 times body weight). Further analysis is needed to analyse head and neck positioning during the bridge and derive peak forces and moments that may lead to severe injuries of the cervical spine.

Axial loading has been shown as the primary cause of severe cervical spine injuries in American football (Torg et al., 1990) and sumo wrestling (Nakagawa, Mukai, Minami, Hattori, & Nakamura, 2017). In both cases, high axial loading occurs as a result of head impact from blocking or tackling. In particular, Torg et al. (1990) performed stop-frame kinetic analysis based on the review of films of actual injuries during professional American football tackles. The reported axial forces during direct collision that led to football-induced cervical spine trauma was reported to be between 400-800 kg. In American football, rule changes to avoid the use of the top of the helmet as the initial point of contact led to a dramatic decrease of reported injuries (Torg et al., 1990). Unfortunately, the loading patterns in schwingen are more complex, comprising a combination of axial loading and rotational forces during dynamic throws and partially fixed positions. Furthermore, the implementation of rule changes, or protective equipment such as a helmet, are very unlikely given the long history of the Swiss tradition (Trieb, 1941).

The observed peak values are within the expected values for the head and the knee. However, the observed peak force on the bank during the landing after the throw was about 10 time the body weight. This shows that even in the sawdust surface, not the entire impact energy is absorbed but a significant load is still present.

Muscular strengthening around the neck and the knee to provide joint stability is considered to play the key role for injury prevention in schwingen. In particular, the delicate structures of the cervical spine, as well as the knee joint, are susceptible to injury without support from the surrounding musculature or when the joints are moved in such a way that the forces and leverage arm cause high rotational moments. Forces can be effectively dissipated by the energy-absorbing capabilities of the musculature through controlled joint motion. A direct association has previously been reported between isometric strength training of the neck or muscular strength and reduced injury risk of the cervical spine in professional rugby union players and high school athletes (Hrysomallis, 2016). Thereby, musculoskeletal simulations and biomechanical analysis of loading conditions can help identify the optimal training exercises for specific muscle strengthening exercises in sports and rehabilitation practice (Plüss, Schellenberg, Taylor, & Lorenzetti, 2018). As such, the most effective movement type and loading condition to strengthen the neck and knee muscles and avoid overloading during schwingen may be derived using the predictive power of musculoskeletal modelling techniques as a next step.

This study has several limitations. The sawdust distributes the applied force to the ground also aside the force plate. Also is the area of the force plate limited. Only the force on the plate can be recorded.

CONCLUSION: Based on the present data, and compared to the literature on American football and sumo wrestling, injury mechanisms at the level of the head, neck and knee in schwingen are likely a result of the applied forces from dynamic throws, in combination with extreme joint ranges of motion during fixed grips and defensive manoeuvres such as the bridge. An extended biomechanical analysis of the applied forces, moments and joint kinematics is recommended to develop targeted injury prevention guidelines.

ACKNOWLEDGEMENTS: We like to thank Prophysics AG for the great support during the measurements as well as the athletes for their performance.

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