A COMPARISON OF A TUCKED BACK SOMERSAULT BETWEEN NOVICE AND EXPERIENCED ACROBATIC GYMNASTS: AN INERTIAL MEASUREMENT APPROACH

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The purpose of the case study was to analyse and compare the kinematics of a backward somersault in acrobatic gymnasts. Four acrobatic gymnasts aged between 8-17 years participated in the study, as two paired partnerships. Kinematic data during a backwards tucked somersault were collected using an XSens Inertial system and whole-body joint angular kinematics were compared between experienced and novice gymnasts. Findings indicate that experienced gymnast produced slightly greater knee flexion and an increased ROM through the take-off phase and a greater adduction/abduction movement during arm swing throughout the somersault. The novice gymnast produced a higher range of flexion/extension and internal/external rotation in the shoulder during the preparation and take-off phases. This indicates that training should focus on developing temporal movement efficiency to enhance effective progression of acrobatic gymnasts.

KEYWORDS: XSens, kinematics, gymnastics, progression.

INTRODUCTION: Acrobatic gymnastics involves a combination of individual and group elements performed to music (Taboada-Iglesias, Santana, & Gutiérrez-Sánchez, 2017). The exercises must include a combination in perfect synchronisation of choreography, individual gymnastic elements and collective acrobatic elements such as holds, throws, catches and human pyramids (Grapton, Lion, Gauchard, Barrault, & Perrin, 2013). A somersault is a crucial skill to learn in acrobatic gymnastics. It accounts for most of a dynamic routine as multiple somersaults are performed by the top throughout. Despite this, little focus has been afforded to the kinematics of acrobatic gymnastics, especially in comparison to tumbling and artistic gymnastics and this is further hindered by misunderstanding in the literature with two articles stating the focus is on acrobatic gymnastics (Mkaouer, Jemni, Amara, Chaabene, & Tabka, 2013; Haering, Huchez, Barbier, Holvoet, & Begon, 2017) that are actually artistic in nature.

When competing in acrobatic gymnastics, the overall score given is divided into three categories: difficulty, artistry and execution. The execution mark is based on how well the movement elements are performed, and as such, a somersault is judged on height, flight and shape of the gymnast, with higher marks awarded for better technique and minimal out of plane movement. Progression of training has been shown to improve performance of high-bar swing technique in artistic gymnastics, with experience enabling gymnasts to link movements and execute more complex skills (Busquets, Marina, Irurtia, Ranz, & Angulo-Barrosa, 2011). Therefore, it would be expected that a novice gymnast would not understand technique as easily as an experienced gymnast due to limited training and skill development.

Inertial measurement units (IMU) are designed to overcome the limitation of fixed capture volume inherent in optical 3D motion capture systems. Wireless IMU such as the XSens MVN Biomech system is able to provide joint kinematics during complex functional movements with small error magnitudes of < 5^{o} (Robert-Lachaine et al., 2017) and is appropriate for assessing acrobatic gymnastics. The aim of the case study is to analyse and compare the take-off, flight and landing phases of a backward somersault between a pair of experienced acrobatic gymnasts and a pair of novice acrobatic gymnasts.

METHODS: Four acrobatic gymnasts aged between 8-17 years participated in the study, as two paired partnerships; one gymnast’s role is the base, providing a platform to launch from and land on, and the other is the top who performs the aerial somersault motion. All participants provided informed consent and the study was approved by the institutional ethics committee. After a warm up, the ‘top’ was secured in a safety harness and performed a backwards tucked somersault from the base’s shoulders. Kinematic data were collected from the top using an XSens IMU system throughout the whole somersault. Each pair completed three repetitions of the somersault with a 2-minute rest period between trials. Kinematic data were downloaded and analysed using the XSens MVN Software determine whole-body joint angular kinematics. Data were subsequently transferred to Microsoft Excel to create movement waveforms and enable comparison in 3-D knee and shoulder motion between the experienced and novice acrobatic gymnasts was completed. Specific key events were identified in the somersault (initiation, take-off and landing) to produce discrete movement phases (preparation, flight, and landing) with joint angle and timeframe data were extracted corresponding to the discrete events and phases.

RESULTS: Bilateral and intra-trial movement waveforms were almost identical for each gymnast so a single trial with only the right-side data presented per gymnast.
In the sagittal plane, both gymnasts stand with legs extended. During the preparation phase both knees begin to flex before extending for take-off. During this phase the experienced gymnast flexes to 108° whilst the novice gymnast flexes to 96°. Both gymnasts follow very similar movement patterns during the preparation and take-off phase however the novice gymnast is slower when taking off and during flight. The experienced gymnast takes-off with the knees flexed before moving into the tuck shape of 121° flexion, whilst the novice gymnast takes-off in a more extended position. A similar difference is observed in landing, with the experienced gymnast landing with flexed knees and the novice with knees in an almost fully extended position. In the frontal plane, the novice gymnast displays a much greater range of movement as the knee abducts to 29° during the preparation phase of the somersault, whereas the experienced gymnast creates a maximum abduction of 6° during this phase. Both gymnasts adduct their knees to a similar magnitude, bringing the feet closer together during take-off and landing. However, during the flight phase, the novice abducts the knees 28°, whilst the experienced abducted to only 7°. Similarly, in the transverse plane the novice gymnast produces a much greater range of movement as the knee internally rotates 4° and externally rotates 14° during the preparation phase. The experienced gymnast primarily externally rotates the knee to 8°. Throughout the flight phase, both gymnasts fluctuate the rotation with the novice gymnast producing larger variation in internal and external rotation angles.

Figure 1. Knee joint kinematics. A: Sagittal plane; B: Frontal Plane; C: Transverse plane. (Blue line – Experienced; Orange line – Novice).

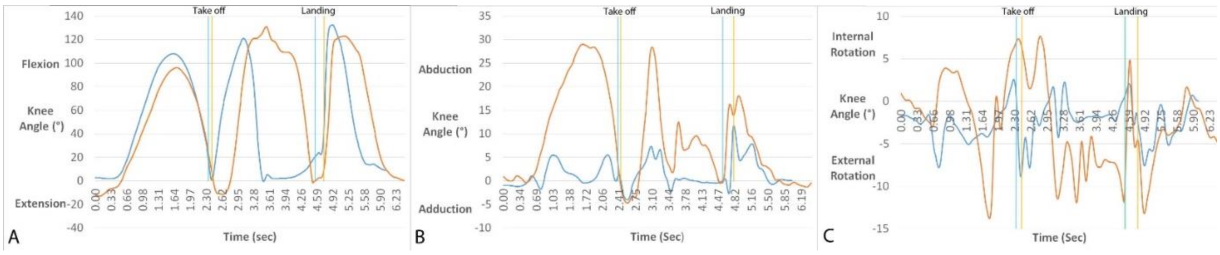

Table 1: Somersault Phase Data of the Knee Joint

Event/Phase	Experienced Time (s) (Range: Duration)	Peak Joint Angle (°) Sagittal	Frontal	Transverse	Novice Time (s) (Range: Duration)	Joint angle (°) Sagittal	Frontal	Transverse
Somersault Initiation	0	3	-1	-2	0	-7	1	-1
Somersault Preparation	0 – 2.36: 2.36	108	6	-8	0 – 2.41: 2.41	96	29	4 and -14
Take-off	2.36	36	2	6	2.41	6	-1	6
Flight	2.36 – 4.52: 2.16	121	7	-9	2.41 – 4.78: 2.37	131	28	8 and -12
Landing	4.52	32	0	2	4.78	6	15	-5
Recovery	4.52 – 6.05: 1.53	133	12	-8	4.78 – 6.40: 1.62	123	18	5 and -13

Positive Orientation: Sagittal – Flexion; Frontal – Abduction; Transverse – Internal Rotation

In the sagittal plane, both gymnasts begin with shoulders in a flexed position. Both extend and flex in a similar movement pattern throughout the somersault. The experienced gymnast extends to 53° in the preparation, whilst the novice gymnast extends to 11° at take-off. During flight the experienced gymnast flexes the arms to 150° at landing, while the novice gymnast reaches 100° flexion at landing but continues to flex beyond this during the recovery phase. In the frontal plane, initially the arms were held in an abducted position. During the take-off phase, the experienced gymnast adducts the shoulders to 20°, bringing the arms to the body, before abducting the shoulders to 48° at take-off. During flight, initially they adduct the shoulders to 0°, then abducting to 60° as they come out of the somersault, In comparison the novice gymnast adducts to only 6° at take-off and produces a smaller range of motion during flight as they initially abduct to 38° and then adduct to 17° as they complete the somersault. In the transverse plane, both gymnasts follow similar movement patterns, however the novice gymnast rotates the shoulder over 90° more than the experienced gymnast in the preparation and recovery phases. The experienced gymnast externally rotates by approximately 60° whilst the novice gymnast rotates approximately 150°.

Figure 2. Shoulder joint kinematics. A: Sagittal plane; B: Frontal Plane; C: Transverse plane. (Blue line – Experienced; Orange line – Novice).

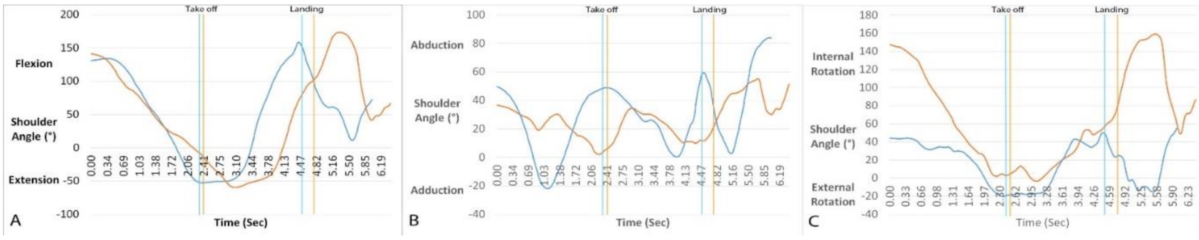

Table 2: Somersault Phase Data of the Shoulder Joint

Event/Phase	Experienced Time (s) (Range: Duration)	Peak Joint Angle (°) Sagittal	Frontal	Transverse	Novice Time (s) (Range: Duration)	Peak Joint Angle (°) Sagittal	Frontal	Transverse
Somersault Initiation	0	129	50	40	0	145	39	148
Somersault Preparation	0 – 2.36: 2.36	131 and -53	50 and -20	40 and -18	0 – 2.41: 2.41	145 and -11	39	148
Take-off	2.36	-52	48	-18	2.41	-11	6	5
Flight time	2.36 – 4.52: 2.16	15 and -53	57	47	2.41 – 4.78: 2.37	100 and -64	38	77
Landing	4.52	150	57	47	4.78	100	20	77
Recovery	4.52 – 6.05: 1.53	150	82	53 and -11	4.78 – 6.40: 1.62	173	55	160

Positive Orientation: Sagittal – Flexion; Frontal – Abduction; Transverse – Internal Rotation

DISCUSSION: This study aimed to compare the take-off, flight and landing phases of a backward somersault between a pair of experienced acrobatic gymnasts and a pair of novice acrobatic gymnasts. The purpose of the observed somersault is to produce one full rotation of the body around the mediolateral axis in the sagittal plane. To enable this the gymnast performs the somersault in a tucked position to reduce the moment of inertia allowing a quicker rotation. The primary aim of the gymnast will be to learn this skill to be able to execute this fundamental movement. As such, generally, movement in the sagittal plane was similar irrespective of experience level at both the knee joint and shoulder joint. The main difference was observed towards the end of the somersault as the experienced gymnast extended their knee and flexed their shoulders earlier and for a longer period of time. It is likely that the experienced gymnast is able to use biomechanical knowledge and adjust their techniques to lengthen the body and increase moment of inertia, slowing down rotation to spot the landing and execute more effectively than the novice gymnast.

In the frontal and transverse planes, the novice gymnast produced a greater range of motion throughout the somersault at the knee joint. Speed and power play an important role in the somersault as they must be able to jump high to create sufficient time to rotate completely (Rice et al, 2018). The experienced gymnast produces minimal adduction/abduction during the preparation and take-off phase, they will be able to generate more power, increasing jump height to produce successful completion of the somersault (Mkaouer et al, 2013). To enable novice gymnasts to produce greater power during take-off, they should be coached to develop technique where the knees stay in a neutral position to maximise the direction of force application. During landing the novice produces greater knee abduction and may increase injury risk as the knee is placed in a valgus position when extended (Gooyers et al., 2012). This may be due to the shorter time period the novice exits the somersault resulting in minimal time to adjust limb orientation before contacting the base. Additionally, during flight the novice produces 18° of rotation that oscillates between internal and external rotation, indicating inferior muscular control of the limbs and may identify an area of technique for coaches to develop to improve artistry.

When comparing the shoulder joint, the novice gymnast produced a higher range of internal/external rotation whilst the experienced gymnast created greater adduction/abduction. The experienced gymnast utilises their arms more by producing a larger range of movement in the preparation and take-off phase to generate angular momentum. The experienced gymnast also displays a smoother waveform during the somersault flight. It is probable that the experience gymnast is utilising the arm swing to stabilise the somersault by increasing the magnitude of abduction and this assists in the ability of the gymnast to increase moment of inertia in conjunction with the shoulder flexion. Greater rotation observed in the novice gymnasts is likely due to lack of control during the somersault (Hart and Carmichael, 1985). Poor arm control will affect the presentation of the somersault, and this is of concern as the technique will affect the subjective scoring by the judges. As the gymnast develops experience in the performance, the control of the arms will improve, resulting in reduced excessive shoulder rotation.

CONCLUSION: This study identified that the greater experience in acrobatic gymnastics produces a smoother and faster preparation and take-off phase into the tucked back somersault, highlighting greater movement control and improved technique. Lack of experience manifests as instability and lack of control in the frontal and transverse plane. This indicates that training should focus on developing temporal movement efficiency in to and exiting the tuck position and improving control in the out-of-plane elements of a somersault to enhance effective progression of acrobatic gymnasts.

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