IDENTIFYING RELEASE FOR HIGH BAR SKILLS

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The release from the high bar for both dismounts and release re-grasp skills is a compulsory part of any high bar routine. Despite the importance of the instant of release there is no definitive scientific method to identify this instant in high bar gymnastics. Various methods of release definitions were compared using automatic motion analysis (200Hz), visual images (200Hz) and bar force (1000Hz). A single elite gymnast performed 5 dismounts and 5 Tkachevs. Differences between bar force derivatives and motion analysis suggest the approach taken can influence the key release parameters. Differences between skills also highlights that a global release definition may not be appropriate and further research should consider skill specific definitions of release from the bar.

KEY WORDS: gymnastics, methodology, event definition

INTRODUCTION: The release is a key part of any high bar routine in Men's Artistic Gymnastics, despite this there is no definitive scientific method to identify the instant of release from the bar. The instant of release is the moment that the trajectory of the gymnast's mass centre is set and is unchangeable until re-grasp or landing (Hiley & Yeadon, 2003). It is important that the performance of the skill preceding release allows for the desired release parameters to be created leading to successful performance of a release re-grasp skill or dismount. Understanding of the instant of release is crucial as this determines the success of the performance of the flight element. Throughout the literature varying definitions have been employed utilising methods from visual cues (Kerwin, Yeadon & Lee, 1990; Hiley & Yeadon, 2005) to measures of grip radius (Harwood, Kerwin & Yeadon, 1991; Kerwin, Yeadon & Harwood, 1993; Kerwin & Irwin, 2010, 2011; Manning, Irwin, Gittoes & Kerwin, 2011) and contact switches (Gervais & Baudin, 1995). Kerwin et al. (1993) initially highlighted the importance of correct release identification when results that appeared mechanically impossible were reported showing the mass centre of the gymnast to be higher than the bar at release for a dismount (Kerwin et al., 1990). Previously, Gervais and Baudin (1995) considered release identification by comparing various methods, however the study was inconclusive and a criterion method of release identification has yet to be established. The importance of accuracy when identifying release was highlighted by Harwood et al., (1991) who stated that measured contributions to velocity and body position can change greatly with the error of one frame when identifying release. The instant of release is not easily identifiable and the impact of the choice of method to define release is still not well understood. The aim of this study was to quantify the effect of release definition on key parameters during the performance of flight elements on high bar.

METHODS: Data Collection: Ethical approval was gained from the University and informed consent given by the participant. A single subject design was adopted in order for differences to be attributable to the methodology and not individual differences. An elite male gymnast (age: 15 years; mass: 59.2 kg; height: 1.63 m) performed five dismounts (full twisting double straight, twisting occurred in the second somersault) and five straddle Tkachevs on a competition standard high bar. Kinematic data were collected using an automated motion analysis system (200 Hz) (CODAmotion, Charnwood Dynamics Ltd., Leicester, UK). Active markers were placed bilaterally on the fifth metatarsophalangeal joint (MTP), lateral malleolus, femoral condyle, greater trochanter, the estimate centre of rotation of the glenohumeral joint, lateral epicondyle of the elbow, ulna styloid process, centre of the bar and 0.5 m to the left and right of the centre of the bar. A video camera (Sony HVR-Z5E, Sony, Japan) was located near to the high bar upright to give a close up view of the gymnast's hands on the bar. The camera operated at 200 Hz with a shutter speed of 1/300 s.

Kinetic data were collected using a high bar instrumented with strain gauges (1000 Hz) outputting data as a voltage. Calibration of the high bar strain gauges was achieved through incremental loading and unloading of the bar with known loads and linear regression incorporating vertical and horizontal stiffness values (Kerwin & Irwin, 2006) was employed to predict vertical and horizontal bar forces from voltage outputs. Synchronisation of data accurate to 0.001 s was achieved using a trigger resulting in a voltage drop and incremental lighting of 20 light-emitting diodes in the field of view.

Data Analysis: The gymnast was assumed to be bilaterally symmetrical throughout the movement and was therefore analysed as planar model (Irwin & Kerwin, 2001). In order to obtain kinematic information for a planar gymnast the mid-points of the joints of the left and right were used throughout the analysis. A residual analysis (Winter, 2005) was used to identify an appropriate cut off frequency to filter the data; residuals were calculated using the toe, hip and wrist markers in both the y and z directions, resulting in a cut of frequency of 11 Hz. Whole body and segmental inertia parameters including centre of mass were calculated based on Yeadon's (1990) inertia model through a method of scaling. Circle angle, vertical velocity and horizontal velocity of the mass centre were identified as variables of interest due to them being key to the gymnast's trajectory during flight. The gymnast's circle angle was defined by the location of the total body mass centre and the location of the centre of the bar relative to the y axis; the gymnast was defined as 90º at handstand and 270º when under the bar. Grip radius was defined as the distance between the gymnast's mid wrists and the centre of the high bar (Irwin & Kerwin, 2008). Release was defined using methods from previous literature and also novel methods. A 1% increase in the maximum grip radius in the preceding longswing ($GR_{1\%}$) (Harwood et al., 1991; Kerwin et al., 1993). A 10% increase in the maximum grip radius in the preceding longswing ($GR_{10\%}$) (Kerwin & Irwin, 2010; Manning et al., 2011). Novel methods included a calculation of jerk using vertical (J_{FZ}), horizontal (J_{FY}) and resultant (J_{FR}) force at the bar. Peak force and oscillation of the force trace are identified; the peak in jerk between those points is then identified as release from the bar. Using a higher order kinematic variable allows for a potentially more robust measure to be employed to identify release. For further reference visual methods of release identification were employed; the first frame in which a clear space was visible between the bar and the gymnast's hands (*HS*) (Kerwin et al., 1990) and the frame before there was a clear space visible between the gymnast's hands and the bar (HS_{-1}) (Hiley & Yeadon, 2005).

RESULTS & DISCUSSION: Release times show that J_{FZ} consistently identifies release earlier than the other methods employed (Table 1). During dismounts methods utilising jerk identify release earlier than those utilising grip radius ($GR_{1\%}$, $GR_{10\%}$) or visual identification (*HS*, HS_{-1}), however during Tkachevs this changes. Release times reported for Tkachevs are earliest using J_{FZ}, however J_{FY} and J_{FR} identify release later than all other methods employed.

Table 1. Average release time (s) for dismounts and Tkachevs reported relative to J_{FZ}.

	Dismount			Tkachev		
J_{FZ}	0.000	±	0.000	0.000	±	0.000
J_{FY}	0.041	±	0.004	0.119	±	0.010
J_{FR}	-0.001	±	0.002	0.117	±	0.009
$GR_{1\%}$	0.127	±	0.002	0.071	±	0.010
$GR_{10\%}$	0.132	±	0.002	0.078	±	0.007
HS	0.129	±	0.005	0.082	±	0.016
HS_{-1}	0.124	±	0.005	0.077	±	0.016

As expected, circle angle is greater for Tkachevs than for dismounts as the gymnast releases later in order to travel backwards over the bar (Table 2). Release angles reported for Tkachevs were all greater than 360º allowing the gymnast to travel back over the bar to re-grasp. Circle angles between 401º and 409º reported for the female Tkachev (Manning et al.,

2011) compare favourably to those reported by methods using horizontal and resultant jerk (J_{FY}, J_{FR}).

Previously Kerwin et al. (1990) found the gymnast's centre of mass to be higher than the height of the bar during dismounts, this highlighted that the instant identified as release may not be correct. If a gymnast released the bar when their mass centre was higher than the height of the bar this would result in a trajectory of the mass centre travelling towards the bar rather than away from the bar as in a dismount (Kerwin et al., 1993). Kerwin et al. (1990) defined release as the instant there was a clear space between the gymnast's hands and the bar (*HS*) with 50 Hz video of the whole gymnast. The same method was employed here with 200 Hz video zoomed in on the gymnast's hands and values below 360^o for circle angle are reported. This provides some support for the suggestion from Gervais and Baudin (1995) that a close up view of the hands may provide a better estimate of release.

The earlier release times identified by methods using jerk (J_{FZ}, J_{FY}, J_{FR}) during dismounts resulted in greater vertical velocities, however differences in horizontal velocities are less clear with greater standard deviations reported compared to methods utilising grip radius ($GR_{1\%}$, $GR_{10\%}$) and visual cues (*HS*, HS_{-1}). Hiley and Yeadon (2003) reported average vertical velocities of 4.83 m·s^{-1}, which reports lower values than methods employing jerk to identify release and higher values than those using grip radius ($GR_{1\%}$, $GR_{10\%}$) and visual identification (*HS*, HS_{-1}). Horizontal velocities reported are greater than the average reported by Hiley and Yeadon (2003) for dismounts as 1.27 m·s^{-1} and Arampatzis and Brüggemann (1999) who reported horizontal velocities of 0.82 m·s^{-1}.

Table 2. Release parameters for dismounts and Tkachevs when using each of the methods of release identification (mean ± SD).

	Circle Angle (^{o})		Vertical Velocity (m·s^{-1})		Horizontal Velocity (m·s^{-1})	
	Dismounts	Tkachevs	Dismounts	Tkachevs	Dismounts	Tkachevs
J_{FZ}	309 ± 0.5	379 ± 2.4	5.1 ± 0.06	3.2 ± 0.10	1.6 ± 0.13	-1.2 ± 0.15
J_{FY}	323 ± 0.9	401 ± 4.0	5.0 ± 0.06	2.0 ± 0.12	1.4 ± 0.12	-1.9 ± 0.12
J_{FR}	309 ± 0.5	401 ± 3.9	5.1 ± 0.06	2.0 ± 0.14	1.6 ± 0.13	-1.9 ± 0.12
$GR_{1\%}$	353 ± 0.9	393 ± 2.9	4.1 ± 0.04	2.3 ± 0.19	1.5 ± 0.10	-1.7 ± 0.10
$GR_{10\%}$	355 ± 1.0	394 ± 2.9	4.1 ± 0.04	2.3 ± 0.18	1.5 ± 0.10	-1.8 ± 0.10
HS	354 ± 1.7	395 ± 3.8	4.1 ± 0.05	2.3 ± 0.14	1.5 ± 0.10	-1.8 ± 0.12
HS_{-1}	352 ± 1.8	394 ± 3.8	4.2 ± 0.05	2.3 ± 0.14	1.4 ± 0.10	-1.8 ± 0.13

Across methods Tkachevs consistently displayed greater standard deviations indicating greater variability across trials, therefore, variability in Tkachevs may be due to variation in performance of the skill rather than variation in the method used to define release.

Images taken from high speed video (200 Hz) of the hand show what is happening at the instant of release from the high bar; Figure 1 shows that using J_{FZ} and J_{FR} to identify release the gymnast is still pulling down on the high bar, these methods report average circle angles of 43^o-46^o less than methods using grip radius ($GR_{1\%}$, $GR_{10\%}$) and visual identification (*HS*, HS_{-1}). Visually grip radius methods ($GR_{1\%}$, $GR_{10\%}$) and visual identification (*HS*, HS_{-1}) produced similar release times for dismounts and this was supported by similar circle angles, vertical and horizontal velocities of the mass centre (Table 2).

J_{FY} and J_{FR} (Figure 2, b; c) identify release when the gymnast is clearly off the bar; this method reported a greater circle angle than other methods where the gymnast still has some contact with the bar. J_{FR} appeared to identify release early during a dismount, however when considering a Tkachev the same method identified release much later; the gymnast is no longer in contact with the bar. This highlighted that the skills being performed needs to be taken into consideration, the gymnast may release the bar in different ways for different skills and therefore a different method of release identification may be more appropriate.

a) b) c) d) e) f) g)

Figure 1. Images of the hand at release using varying methods of release identification during a dismount; a) J_{FZ}, b) J_{FY}, c) J_{FR}, d) $GR_{1\%}$, e) $GR_{10\%}$, f) *HS*, g) HS_{-1}.

a) b) c) d) e) f) g)

Figure 2. Images of the hand at release using varying methods of release identification during a Takchev; a) J_{FZ}, b) J_{FY}, c) J_{FR}, d) $GR_{1\%}$, e) $GR_{10\%}$, f) *HS*, g) HS_{-1}.

CONCLUSION: High-speed video provides valuable insight into the validation of different methods employed to identify release from the high bar. This study highlighted that there are variations in skills and release definition and therefore a definition employed may need to be skill specific. A global release definition may not be appropriate and further research should investigate skill specific definitions of release from the bar.

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