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Full Length Article

# The role of functional variability in a whole body co-ordinated movement – Application to high bar giant circles

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ABSTRACT

When performing a giant circle on high bar a gymnast flexes at the hips in the lower part of the circle, increasing the kinetic energy, and extends in the upper part of the circle, decreasing the kinetic energy. In order to perform a sequence of giant circles at even tempo, any variation in angular velocity at the end of the flexion phase needs to be reduced by the end of the extension phase. The aim of this study was to determine the nature and contribution of such adjustments. A computer simulation model of a gymnast performing giant circles on high bar was used to investigate strategies of (a) fixed timing of the extension phase (feedforward control) and (b) stretched timing in order to extend at the same point of the giant circle (feedforward with additional feedback control). For three elite gymnasts fixed timing reduced the angular velocity variation on average by 36% whereas stretched timing reduced the variation by 63%. The mean reduction for the actual gymnast techniques was 61%. It was concluded that both feedforward and feedback control strategies are used by gymnasts for controlling such movements.



## 1. Introduction

In discrete rapid movements an athlete may select an overall duration for performing the task (Shapiro, 1977) which is then carried out in a feedforward (open loop) manner. In such cases the relative timing of events within the movement has been shown to be invariant, in that all components of the movement are scaled in time (Shapiro, 1977). In ongoing tasks, that are longer in duration, pace may be regulated using feedback (closed loop) control (Jagacinski & Flach, 2003).

When a gymnast performs regular giant circles on the high bar (Fig. 1) the aim is to swing with as little deviation in body form as possible (i.e. minimal use of the hip and shoulder). Regular giant circles are used to link skills performed within a high bar routine. If the circles are used to increase the gymnast's average angular velocity about the bar, in preparation for a release or dismount skill, they are referred to as accelerated giant circles (Cheetham, 1984). The gymnast and bar are a mechanical system, where the gymnast can use muscular actions at the hip and shoulder to input or dissipate energy (Bauer, 1983; Yeadon & Hiley, 2000). As the gymnast passes beneath the bar, the hip and shoulder angles are closed (hip flexion and shoulder extension) which increases both the potential and kinetic energy in the system (Bauer, 1983; Sevrez, Berton, Rao, & Bootsma, 2009). As the gymnast passes through the upper part of the circle, opening the hip and shoulder angles increases the potential energy but decreases the kinetic energy. By varying the timing and amount of extension

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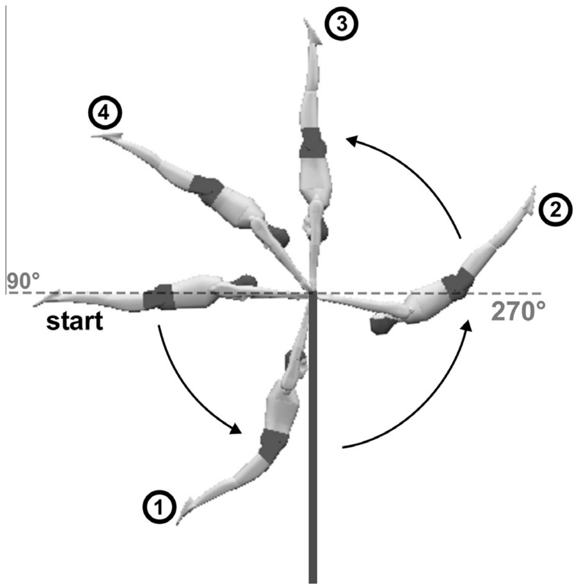


**Fig. 1.** Giant circle showing points of greatest opening (① and ③) and closing (② and ④) of the hip and shoulder.

(opening the hip and shoulder angles) the gymnast can control the energy within the system and thus regulate the speed of rotation.

Hiley, Zuevsky, and Yeadon (2013) showed that in consecutive regular giant circles, where the gymnasts had been instructed to perform the circles with good form and even tempo, the mechanically important actions (called the "tap", Fig. 1① to ②) in the lower part of the circle were performed with low spatial and temporal variability. However, in the actions performed as the gymnasts passed through the upper part of the circle (Fig. 1② to ④), the movement variability was found to be significantly higher. It was speculated that the higher variability was due to the gymnasts making feedback corrections in order to keep the giant circles on time (Hiley et al., 2013). Sevrez et al. (2009) attached weights to gymnasts' legs to increase the moment of inertia about the bar during regular giant circles. When looking at the actions performed beneath the bar it was reported that with changing duration of the circle, due to increased moment of inertia, the gymnasts' actions were invariant in terms of the position within the circle rather than being temporally invariant. No data were reported on the gymnasts' extension through the upper part of the circle.

Movement variability is often reported to have a functional role, which is referred to as the flexibility or adaptability of the system to external variability (Bartlett, Wheat, & Robins, 2007; Hamill, van Emmerik, Heiderscheit, & Li, 1999; Preatoni et al., 2013). An increase in movement variability associated with a gymnast making feedback corrections would fall under the definition of functional variability since the adjustments have the function of controlling the pace of the giant circle. Feedback control has been demonstrated in a number of gymnastics activities such as hand balance (Yeadon & Trewartha, 2003) and twisting somersaults (Yeadon & Hiley, 2014; Yeadon & Mikulcik, 1996). In both cases the control strategy was based on detecting an error in the desired state and providing a correction, based on the mechanics of the system, after an appropriate time delay (Jagacinski & Flach, 2003; Latash, 1998). When looking at repeated trials of the same skill it may therefore appear as though there is increased movement variability in certain aspects due to feedback control. However, in order to maintain low variability in the outcome of the movement each feedback correction must still be performed with accuracy (Yeadon & Hiley, 2014).

The aim of the present study is to determine the nature and contribution of technique and adjustments to the control of pace during consecutive regular giant circles. This comprises the contributions of feedback control, feedforward control and any passive control inherent in the gymnast – bar system.

## 2. Methods

The variability within consecutive giant circles performed by elite gymnasts was determined and was compared with the variability of simulated strategies.

### 2.1. Data collection

Three elite male gymnasts (age 21 ± 3 years, mass 69.8 ± 1.6 kg, height 1.72 ± 0.03 m) who competed internationally gave informed consent to participate in the study which was approved by the university's ethics committee. The gymnasts