MOVEMENT REGULATION OF THE GLIDE KIP IN GYMNASTICS

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Abstract
Successfully performing the glide kip in gymnastics depends on how the feet can pass the ground below the bar. The aim of this study was to examine the perceived size of the space between the bar and the ground operating as an informational source in the regulation of the glide kip in gymnastics. It was hypothesized that parameters that are spatially related to this informational source should vary as a function of the distance between bar and mats. To test this hypothesis, N = 13 gymnasts were asked to perform glide kips, while the size of the space between the bar and the mat was systematically manipulated. Results revealed that the distance of the tiptoes to the ground was regulated in an invariant manner based on the perceived space between the bar and the mat during the glide phase. Regulating the distance of the tiptoes may serve as a visual reference in the performance of a glide kip in a constrained movement situation. It is stated that knowledge about relationships between informational sources in the environment and the resulting regulatory processes in gymnasts may help coaches to develop specific training programmes for the acquisition of complex skills.

Key words: visual perception, constraints, artistic gymnastics, complex skill performance

Introduction
In gymnastics the glide kip is a fundamental skill for beginners and also an important skill for expert gymnasts when performing compulsory and optional routines in training and competition (Arkaev & Suchilin, 2004). Successfully performing the glide kip primarily depends on how the feet can pass the ground below the bar, since the space available below the bar significantly constrains the skill. This is especially true, if the kip is performed on the lower bar of the uneven bar apparatus or on a lowered high bar apparatus which is a typical training aid in gymnastics (Turoff, 1991). Skilled gymnasts are thought to perceive relevant environmental information directly and use that information to regulate their movements (Raab, de Oliveira, & Heinen, 2009).

However, the question arises, on which informational source(s) this regulation is based on when performing gymnastics skills in environmentally constrained movement situations? The aim of this study therefore was to examine the perceived size of the space between the bar and the ground operating as an informational source in the regulation of the glide kip in gymnastics. Comprehensive work has been done regarding the biomechanical analysis of the glide kip in gymnastics (e.g., Brüggemann, 1994; Reid & Kopp, 1983; Mooney, 1977). For instance, coordination profiles of the body joints and segments together with the trajectory of the center of mass were analyzed in order to gain a better understanding of the mechanisms of the kip movement. Lately, even complex simulation models utilizing and examining different optimization approaches when performing a glide kip have been developed in the mentioned context(e.g., Dareru, Joo, & Miyazaki, 2000; Yamasaki, Gotoh, & Xin, 2010). However, research has thus far neglected the role of visual information in the performance of a glide kip in gymnastics. Research on human locomotion and obstacle avoidance as well as on human grasping tasks highlight the role of visual information in (end point) trajectory formation and control (Jeannerod, Arbib, Rizzolatti, & Sakata, 1995; Patla, 1997).

Visual information about the environment is integrated with information due to self-motion in order to plan and adjust the movement kinematics based on the circumstances of the movement situation (Raab et al., 2009), and recent theoretical approaches argue that athletes in general use the information that can directly guide their action (Withagen & Michaels, 2005). From the outlined perspective, the main aim of the current study was to examine the role of the space between the bar and the ground in the regulation of the glide kip in gymnastics. It was hypothesized that the perceived size of the space between the bar and the mat not only constrains kip performance but is also a relevant informational source for performing a glide kip. Parameters that are spatially related to this informational source, such as the distance of the tiptoes to the ground, should vary as a function of the distance between bar and mats. To test this hypothesis, gymnasts were asked to perform glide kips in a constrained movement situation, while the size of the space between the bar and the mat was systematically manipulated.
Methods

Participants
N = 13 female gymnasts (age: 15 ± 2 years, body weight: 40 ± 8 kg, body height: 159 ± 0.12 cm, average training: 8 ± 2 years). Gymnasts reported to participate in the regional championships. At the beginning of the experiment, the gymnasts gave their informed written consent. The experiment was carried out in accordance with the ethical guidelines and the approval of the university’s ethical committee. The gymnasts were not explicitly informed about the experimental manipulation to ensure that they remained in principle naive to the experimental conditions.

Task and Measures
The experimental task was a glide kip on a high bar apparatus simulating the lower bar of women’s uneven bars. Figure 1 presents a stick-figure drawing of the gymnastics apparatus used in our study (Enoka, 2002). The camera operated with a sampling rate of 120 Hertz (temporal error: ± 0.00833 s) and at a spatial resolution of 640x480 pixels (spatial error: ± 0.005 m). A reflective marker was attached to the right toe. The horizontal and vertical coordinates of this marker were extracted from the videotaped sequences using the movement analysis software Simi Motion© version 8.5 (Simi Reality Motion Systems, 2012). From the position data of the marker the distance of the tiptoes to the mat was calculated.

Kinematic Analysis
A digital video camera recorded the glide kip. The optical axis of the camera was adjusted to the plumb line from the bar to the mats beyond the bar. The camera was placed 15.00 meters away from the bar, ensuring that the complete skill could be recorded. The camera thus captured visual field of approximately 3.40 meters width. The visual field was calibrated by means of a 3.00 x 2.00 meter calibration frame (Enoka, 2002). The camera operated with a sampling rate of 120 Hertz (temporal error: ± 0.00833 s) and at a spatial resolution of 640x480 pixels (spatial error: ± 0.005 m). A reflective marker was attached to the right toe. The horizontal and vertical coordinates of this marker were extracted from the videotaped sequences using the movement analysis software Simi Motion© version 8.5 (Simi Reality Motion Systems, 2012). From the position data of the marker the distance of the tiptoes to the mat was calculated.

Procedures
The experiment was conducted in three phases. All participants were tested individually. In the first phase the gymnast arrived at the gym and completed the informed consent form. The gymnast was informed about the general purpose and the procedure of the study. In particular, the gymnast was told that she takes part in a study on the kinematics of the glide kip on the uneven bars. Afterwards the gymnast was given a 20-minute individual warm-up phase. At the end of the warm-up the gymnast was allowed three practice trials in which the bar height and the mat level height were set to the values of the baseline condition. This was done to ensure that gymnasts’ motor system was adjusted to the particular apparatus used in our study (Enoka, 2002). The second phase took place after the three practice trials were completed. The gymnast was asked to perform four glide kips in the baseline condition and in each of the three experimental conditions for a total of 16 glide kips. The experimental conditions were presented in a blockwise fashion. The order of the three blocks was randomized for each gymnast. The gymnasts were not explicitly informed about the experimental manipulation to ensure that they remained in principle naive to the experimental conditions. After performing four kips in each condition, the gymnast was asked to take a short 5-minute break in the locker room. During this period the mats were rearranged according to the gymnasts’ individual experimental protocol. When performing the glide kips in each condition, breaks were allowed as requested. There was no time pressure during the experiment. After the 16 glide kips were completed, the gymnast was given a 20-minute individual cool-down phase. A manipulation check was conducted by asking the gymnast if she had perceived any experimental manipulation during the experiment, and if she performed the glide kips different due to that perception. All gymnasts indicated that they had perceived the different situation of the mats below the bar.

Experimental Protocol
The gymnasts had to perform n = 4 glide kips in each of three experimental conditions, and in the baseline condition for a total of 16 kips (Figure 2). In all conditions the high bar was set at a height of 1.70 meters from the ground. In the first condition (baseline condition), a stack of standard gymnastics mats was put under the bar giving an approximate height of 0.22 meters from the ground. In the second condition, the mats on the backside of the bar were lowered to a height of 0.11 meters (lowered mat condition) whilst in the third condition the mats on the back side of the bar were elevated to a height of 0.33 meters (elevated mat condition). The fourth condition comprised an elevated stack of mats of 0.33 meters height in front of and behind the bar (elevated base condition). Each gymnast began with performing the four kips in the baseline condition. Following this, the remaining three experimental conditions were presented to the participating gymnasts in a blockwise and randomized order.
However, none of the gymnasts reported having performed the glide kips differently. After the manipulation check the gymnast was debriefed.

Data Analysis
First, the time courses of the distance of the tiptoes to the ground were averaged and time-normalized for all trials of each gymnast and each condition. For the time-normalization the beginning of the glide phase was set at 0% and the end of the pike phase was defined as 100% of the time-course (Figure 3). Second and given that regulative processes may occur at several parts in the time-course, significant events in the time course of the experimental condition (initial values, local minima) which were related to the main hypothesis of this study, were subjected to the statistical analysis. In particular and in order to assess differences in distance of the tiptoes to the ground between the experimental conditions, t-tests for paired samples were calculated, and a significance criterion of \( \alpha = 5\% \) was defined for all reported results (O’Keefe, 2003).

Results

![Image](image-url)

Figure 1. Stick-figure sequence and corresponding movement phases of the glide kip in gymnastics (cf., Mooney, 1977)

![Image](image-url)

Figure 2. Illustration of the four conditions realized in this study: a) baseline condition, b) lowered 2nd mat, c) elevated 2nd mat, d) elevated base. Note: Gymnasts always started on the left side of the bar while grasping the bar (cf), (Figure 2).

It was expected that the perceived size of the space between the bar and the mat is a relevant informational source for performing constrained swinging in gymnastics in general, and for performing the glide kip in particular. It was argued that parameters that are spatially related to this distance, such as the distance of the tiptoes to the ground, should vary as a function of the distance between bar and mats. Figure 3 presents the time-normalized course of the distance of the tiptoes to the ground in the baseline condition and in the three experimental conditions. It can be seen that in the baseline condition and the lowered mat condition tiptoes are continuously lowered from the beginning of the glide phase (= 0%) towards approximately 50% of the time course (end of the glide phase). They are raised afterwards continuously toward the end of the pike phase (= 100%). In the elevated mat condition and in the elevated baseline condition, the tiptoes are initially raised (25-30% of the time-course). They are then lowered towards the end of the glide phase and they are raised again towards the end of the pike phase. Complementary to the description of the time-course, two particular and statistically significant results should be emphasized here. First, at the beginning of the glide phase (= 0% in the time-course) there were significant differences in the distance of the tiptoes to the ground between the elevated baseline condition (mean: 0.49 ± 0.06 m) and the remaining three conditions (mean: 0.42 ± 0.06 m), \( t(12) = 2.225, p = .046, \) Cohens \( d = 0.65 \).
However, when normalizing the average distance of the tiptoes to the height of the mat, the significant difference disappeared, indicating that the distance of the tiptoes to the ground is regulated based on the perceived space between the bar and the mat already at the beginning of the glide kip. On average gymnasts exhibited a distance between the tiptoes to the mat of 0.20 ± 0.06 meters. Second, towards the end of the glide phase there were significant differences in the minimal distance of the tiptoes to the ground between the baseline condition (0.35 ± 0.05 m) and the lowered mat condition (0.26 ± 0.05 m), t(12) = 7.280, p < .05, Cohens’ d = 2.08, between the baseline condition and the elevated mat condition (0.476 ± 0.05 m), t(12) = 6.918, p < .05, Cohens’ d = 2.00, between the baseline condition and the elevated base condition (0.464 ± 0.05 m), t(12) = 5.767, p < .05, Cohens’ d = 1.66, between the lowered mat condition and the elevated mat condition, t(12) = 14.268, p < .05, Cohens’ d = 4.11, and between the lowered mat condition and the elevated base condition, t(12) = 12.115, p < .05, Cohens’ d = 3.46. However, when normalizing the average distances of the tiptoes to the height of the stack of mats behind the bar, the significant differences disappeared, indicating that also the glide phase is regulated based on the perceived space between the bar and the mat. On average, gymnasts exhibited a minimal distance between the tiptoes and the mat of 0.14 ± 0.05 meters towards the end of the glide phase.

Discussion and conclusion

The main goal of this study was to investigate the role of the perceived space between the bar and the mat in the regulation of the glide kip in gymnastics. This goal was approached by asking gymnasts to perform glide kips while the size of the space between the bar and the mat was systematically manipulated. It was hypothesized that the perceived size of the space between the bar and the mat not only constraints kip performance but is also a relevant informational source for performing a glide kip. Taking the results of the current study together, it becomes apparent that gymnasts utilize the perceived space between the bar and the mat as an informational source to control the glide kip in gymnastics. The distance of the tiptoes to the mat seems to be regulated in an invariant manner already prior to the beginning of the glide phase since the average tiptoes-mat distance was invariant between the experimental conditions. The same pattern of results emerged for the distance of the tiptoes to the mat during the glide phase. Taken together, this result is in line with studies aiming at examining the role of different informational sources on movement kinematics (cf., Heinen, Jeraj, Thoeren, & Vinken, 2011). It can thus be argued that visually perceiving the space between the bar and the mat guides the performance of the glide kip in gymnastics. Regulating the distance of the tiptoes to the mats in an invariant manner may therefore serve as a visual reference in the performance of a glide kip in a constrained movement situation (Davids, Button, & Bennett, 2008; Raab et al., 2009). An advantage of utilizing vision in the glide kip is that it may enable the gymnast to make small corrections throughout the glide phase, which may enable her to reach an adequate piked position prior to the kip phase. In this sense it may also enable the gymnast to adjust the glide phase in every trial to accurately perform the pike and kip phase with an optimal movement quality. However, setting the height of the bar is still common training practice in gymnastics.

Gymnasts typically start from the same position and the same height when performing glide kips on the uneven and/or parallel bars. This, however, ignores the potential effects of a variable training schedule, which could potentially equip the gymnast with the necessary experience to adjust for changing environments in training and competition (Schmidt & Wisberg, 2008). Therefore, the coach should encourage learners to practice the glide kip under varying conditions. This can easily be achieved by practicing the kip on bars of different heights together with different initial positions. It is stated, that gymnasts regulate the glide kip in a constrained movement situation on the basis of the visually perceived space between the bar and the mat. Knowledge about relationships between informational sources in the environment and the resulting regulatory processes in gymnasts may help coaches to develop specific training programs for the acquisition of complex skills.

References


* * * (2012). *Simi Motion version 8.5*. Germany: Unterschleissheim.

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**REGULACIJA POKRETA KLIZNE SKLOPKE U GIMNASTICI**

**Sažetak**

Uspješno izvođenje klizne sklopke u gimnastici ovisi o tome kako stopala mogu proći tlom ispod šipke. Cilj ovog istraživanja bio je utvrditi opaženu veličinu prostora ispod između šipki i tla operativno kao informacijski izvor u regulaciji klizne sklopke u gimnastici. Pretpostavljeno je da će parametri koji su spoznajno povezani s ovim izvorom informacija varirirati u funkciji udaljenosti između šipki i strujanja. Kako bi testirali ovu hipotezu, N = 13 gimnastičara je zamoljeno da izvedu sklopku, dok je prostor između šipki i strujanja bio sistematski mijenjan. Rezultati su pokazali da je udaljenost od prstiju do tla manipulirana na nepromjenjiv način temeljeno na procjeni prostora između šipki i strujanja za vrijeme klizne faze. Regulacija udaljenosti od prstiju može služiti kao vizualna referanca u izvođenju klizne sklopke u situaciji ograničenja pokreta. Zaključeno je kako znanje o relacijama između informacijskog izvora u okruženju i rezultirajućeg procesa regulacije u gimnastici može pomoći trenerima da razviju specifične trenažne programe za usvajanje kompleksnih vještina.

**Ključne riječi:** vizualna percepcija, ograničenja, gimnastika, izvođenje složenih vještina

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