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TARGET-DIRECTED RUNNING IN GYMNASTICS: THE ROLE OF THE SPRINGBOARD POSITION AS AN INFORMATIONAL SOURCE TO REGULATE HANDSPRINGS ON VAULT

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AUTHORS: Heinen T.[1], Jeraj D.[1], Thoeren M.[1], Vinken P.M.[1,2]

[1] German Sport University Cologne, Institute of Psychology, Am Sportpark Müngersdorf 6, 50933 Cologne, Germany
[2] Leibniz University Hannover, Institute of Sport Sciences, Am Moritzwinkel 6, 30167 Hanover, Germany

Reprint request to:
Thomas Heinen
German Sport University Cologne
Institute of Psychology
Am Sportpark Müngersdorf 6
50933 Cologne
Phone: +49 221 4982 - 5710
Fax: +49 221 4982 - 8320
Email: t.heinen@dshs-koeln.de

ABSTRACT: Empirical evidence highlights the role of visual information to control gymnastics vaulting and thus neglects a stereotyped approach run. However, there is no evidence on which informational source this regulation is based on. The aim of this study was to examine the position of the springboard as an informational source in the regulation of the handspring on vault. The hypothesis tested was that the action of running towards the springboard brings about changes in the approach run kinematics and handspring kinematics that relate directly to the position of the springboard. Therefore, kinematics of N = 14 female expert gymnasts' handsprings on vault and their approach runs were examined while manipulating the position of the springboard. The results revealed that expert gymnasts placed their feet on average in the same position on the springboard and adapted to the springboard position during the last three steps of the approach run. A smaller springboard distance to the front edge of the vaulting table resulted in a different hand placement on the vaulting table, a shorter first flight phase, a take-off angle closer to 90° and a longer second flight phase. Findings suggest that the position of the springboard is a relevant informational source in gymnastics vaulting. We state that knowledge about relationships between informational sources in the environment and the resulting regulatory processes in athletes may help coaches to develop specific training programmes in order to optimize performance in complex skills.

KEY WORDS: experimental study, kinematic analysis, direct perception

INTRODUCTION

Gymnastics vaulting is one of many sporting events that involves running towards a stationary target in combination with an accurate placement of the feet on the springboard and the hands on the vaulting table in order to successfully perform a complex vault. Trained gymnasts are thought to directly perceive relevant environmental information that can be used to regulate their movements continuously [4,23]. However, there is no empirical evidence on which informational source this regulation is predominantly based on in gymnastics vaulting. The aim of this experiment was to examine the position of the springboard as an informational source in the regulation of the approach run and the performance of the handspring on vault in gymnastics.

Comprehensive work has been done regarding the biomechanical analysis of the handspring on vault in gymnastics [6]. Dainis [7] developed a mathematical model for vaulting, highlighting the relevant variables that most strongly affect handspring on vault performance. It was found that parameters related to the take-off, such as take-off velocity and the initial distance from the horse, were the principal variables that affected the outcome of the vault. For instance, a defined decrease in horizontal and vertical take-off velocity from the springboard led to an almost two to three times as big decrease in the distance of the second flight phase. The model proposed by Dainis [7] assumed a rather deterministic relationship between the parameters in question, ignoring possible regulation processes when performing handsprings on vault, and thus ignoring the approach run. Furthermore, the author had only N = 4 handspring performances as the model input and hence the generalizability of the results is questionable.

Takei [25] analysed kinematic parameters of handspring performances of N = 24 female gymnasts and correlated these parameters with judge's scores. It could be shown that parameters such as initial velocity, contact time on the horse and time of the second flight phase were significantly correlated with judge's scores. The studies by Dainis [7] and Takei [25] provide significant insight into the movement structure of the handspring vault. However, they do not provide answers to the question of how the handspring may be regulated depending on environmental information.

Today, there is compelling evidence that in target-directed tasks, visual regulation processes are utilized to adjust movement kinematics in order to intercept some object in the environment such as the take-off board in long jumping or the springboard in gymnastics [5,17,21]. The idea of continuous visual control in target-directed tasks is closely related to the theory of direct perception [12]. It considers that light patterns reaching the eye are invariantly related to their sources in the environment and therefore the object can be directly perceived [26]. As a consequence, perceptual information is thought to guide actions while, simultaneously, action informs perception in a continuous and dynamic manner [23].

Hence in a target-directed task where many informational sources are available in the environment, athletes in general use the information that can directly guide their action [23]. The process of selecting the informational sources occurs during learning when athletes become attuned to the most useful information that can guide a given task [26]. Thereafter the execution of a task is tightly coupled to the use of the relevant information [21].

Meeuwsen and Magill [19] analysed for instance the running kinematics of N = 6 gymnasts when performing a sprint run or when performing an approach run with a subsequent handspring on vault. The authors found an increase in the standard deviation in footfall position during the final two steps and the hurdle when gymnasts performed a handspring. They concluded that gymnasts use visual information to regulate the last two steps and the hurdle when performing a handspring on vault. However, the authors provide no conclusion on which informational source this regulation is based on.

Bradshaw [4] had N = 5 elite female gymnasts perform round-off entry vaults. She could show that the visual control onset for the approach run was two steps prior to the hurdle of the round-off and that an earlier visual control onset was positively related to judge's scores. However, three out of five gymnasts performed different variations of the round-off entry vaults. Even if this may not account for differences in the regulation of the approach run, Bradshaw [4] neither experimentally nor statistically controlled for this aspect. Additionally, in both of the aforementioned studies, the authors inferred visual control from the calculation of kinematic parameters from the natural movement behaviour of the participants. They did not use an experimental manipulation to examine the role of different informational sources in the regulation of the approach run and vault performance. Nevertheless, when taking the results of both studies together there is evidence for visual control in the regulation of the approach run in gymnastics vaulting.

From the theory of direct perception [12] we argue that expert gymnasts directly perceive informational sources in the environment that can be used to guide their movements continuously. What could these informational sources be? From the experience of high-level coaches and elite gymnasts [1] we assumed that the position of the springboard is a relevant informational source in gymnastic vaulting. Therefore, the aim of the current study was to examine the role of the springboard position as an informational source in the regulation of the approach run and the performance of the handspring on vault.

In particular, we expected one of the following two patterns of results: First, if the position of the springboard is a relevant informational source, then parameters that are temporally or spatially related to that informational source, such as the placement of the feet on the springboard, should be uninfluenced by a manipulation of the position of the springboard (cf. [3]). Parameters related to prior movement phases should, as a consequence, be influenced by a manipulation of the position of the springboard.

Second, if the position of the springboard is not a relevant informational source, then parameters that are temporally or spatially related to that source should vary as a result of a manipulation of the springboard position. In addition, parameters related to prior movement phases should be uninfluenced by a manipulation of the position of the springboard since there is no necessity to regulate the skill. We had no specific predictions on the effects of a manipulation of the springboard on further kinematic parameters of the handsprings on vault but additionally sought to explore this effect.

MATERIALS AND METHODS

Participants. N = 14 female gymnasts (Mage = 19.00, SD = 2.42 years) volunteered to participate in this study. The gymnasts reported to have national experience, such as participation in the German national gymnastics championships or in the German national gymnastics leagues. They had an average training experience of 11.21 years. We decided to recruit expert gymnasts because experts are already attuned to the most useful informational sources that can guide their action [23]. The gymnasts were informed about the general procedure of the study and gave their written consent prior to the experiment, which was carried out in accordance with the ethical guidelines and with the approval of the German Sport University Cologne. The gymnasts were not informed about the experimental manipulation to ensure that they were naive to the three experimental conditions.

Tasks and Materials

Experimental Task

The experimental task was a handspring on vault. The vaulting table was arranged as it would be in an international competition with a running track in front of the table, landing mats (0.20 m high) behind the table and a certified springboard (1.20 m long and 0.60 m wide) in front of the table. The vaulting table was adjusted to a height of 1.25 m, which matched the international competition guidelines for female artistic gymnastics [11]. Figure 1 shows the criterion movement and the approach run. The length of the approach run (RUL) describes the distance between the leading edge of the vaulting table and the starting point of the approach run. The distance of the toes to the leading edge of the springboard characterizes the placement of the feet on the springboard (FD) and the springboard distance (SBD) is the distance of the leading edge of the springboard to the leading edge of the vaulting table (see Fig. 1). The distance of the wrists to the back edge of the vaulting table characterizes the placement of the hands on the vaulting table (WD).

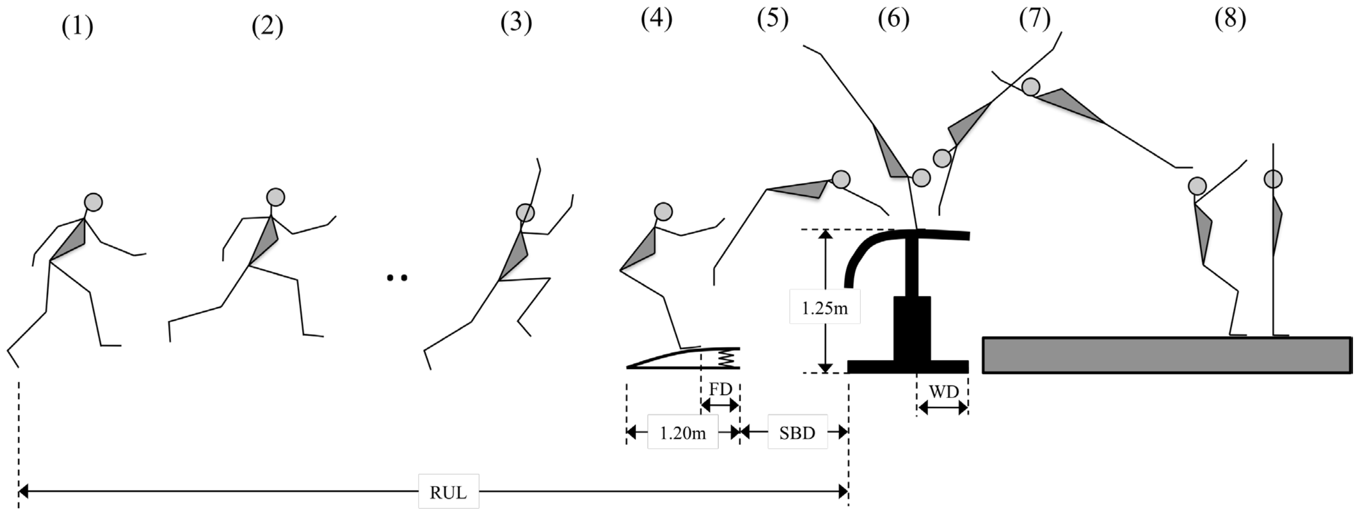

FIG. 1. STICK-FIGURE SEQUENCE OF THE HANDSPRING ON VAULT (FD = DISTANCE OF FEET TO LEADING EDGE OF SPRINGBOARD, SBD = DISTANCE OF SPRINGBOARD TO LEADING EDGE OF VAULTING TABLE, WD = DISTANCE OF WRISTS TO THE BACK EDGE OF THE VAULTING TABLE, RUL = LENGTH OF APPROACH RUN). THE NUMBERS 1 TO 8 CORRESPOND TO THE MOVEMENT PHASES

The approach run can be subdivided into three phases: (1) first step, (2) sprint run and (3) last step and hurdle. From an upright stand the gymnast places one of her feet on the ground (first step). With the first step the gymnast passes over in a short sprint run which ends in the last step and a hurdle movement. At the end of the hurdle the gymnast places both feet on the springboard (4).

The handspring can be subdivided into five phases: (4) take-off, (5) first flight phase, (6) repulsion phase, (7) second flight phase and (8) landing phase [6]. The aim of the approach run is to achieve a sufficient level of kinetic energy which is then used and transferred in the subsequent phases [22]. During the take-off phase the kinetic energy from the approach run is transferred into a whole body rotation about the transverse axis. Furthermore, the gymnast has to generate an optimal centre of mass velocity prior to the first flight phase. The aim of the first flight phase is to reach an optimal support in order to prepare the repulsion phase. In the repulsion phase the horizontal and vertical velocities are altered and the angular momentum is reduced [1]. The goal of the second flight phase is to achieve optimal height, optimal distance and sufficient rotation in order to land in an upright position. The kinetic energy is dissipated during the landing [25].

Experimental Protocol

The gymnasts had to perform $N = 5$ handsprings in each of two experimental conditions, and in the baseline condition for a total of 15 handsprings. In the baseline condition the springboard was placed at the gymnast's individual springboard distance (ISD). In the first experimental condition the individual springboard distance was shortened 0.10 m so that the springboard was placed 0.10 m closer to the leading edge of the vaulting table (ISD – 0.10 m). In the second experimental condition the individual springboard distance was extended 0.10 m so that the springboard was placed 0.10 m farther away from the leading edge of the vaulting table (ISD + 0.10 m). The three conditions were presented to the participating gymnasts in a pseudo-random order, with the rule of not presenting a condition more than twice in a row [10].

Kinematic Analysis

An optical movement analysis system was used to determine the approach run kinematics and handspring kinematics on the basis of video-taped sequences of all performed handsprings. Two of four digital video cameras (sampling rate: 50 Hz, temporal error: ± 0.02 seconds, spatial resolution: 1920 x 1280 pixels) were placed 25 m away from and orthogonal to the running track. The optical axis of the first camera was 18.75 m away from the leading edge of the vaulting table. The optical axis of the second camera was 6.25 m away from the leading edge of the vaulting table. The two cameras recorded a visual field of 13.00 m width and they were calibrated to the movement plane of the gymnasts with the help of a 12.50 × 3.00 m calibration frame (spatial error: ± 0.006 m; cf. [2]). The third camera was placed 25 m away from and orthogonal to the vaulting table. Its optical axis was adjusted to the middle of the vaulting table in order to record the handspring performances. It was calibrated with a 6.00 × 3.00 m calibration frame (spatial error: ± 0.003 m). A frame rate of 50 Hz was deemed as sufficient for the kinematic analysis of the approach run [9,22]. However, the take-off phase and the repulsion phase exhibit rather short phase durations [6]. Therefore, an additional video camera with a sampling rate of 300 Hz was placed orthogonal to the centre of the springboard and the vaulting table in order to measure the initial placement of the feet on the springboard and the initial placement of the hands on the vaulting table. It was calibrated with a 4.00 × 3.00 m calibration frame (temporal error: ± 0.003 s; spatial error: ± 0.005 m).

We analysed the horizontal positions of the toes during each step of the approach run, during the initial contact on the springboard and during the landing as well as the position of the wrists during the initial contact on the vaulting table. From the positions of the toes during the approach run we calculated the difference in absolute foot placement between the two experimental conditions and the baseline condition.

We also recorded the horizontal and vertical coordinates of eight points (body landmarks) defining a 7-segment model of the human body of all handspring performances (cf. [13]). We started this analysis five frames prior to the touchdown of the feet on the springboard and stopped it five frames after the touchdown of the feet on the landing mat during the landing phase. All coordinates were recorded for each trial using the movement analysis software WINanalyze 3D [20]. A digital filter (cut-off frequency = 6 Hz) for data smoothing was applied. Body segment parameters were calculated on the basis of the individual anthropometric properties of each gymnast.

Time-discrete kinematic parameters for the handspring on vault were calculated. With the help of a biomechanist and a top-level gymnastics coach, we chose twelve kinematic parameters from our movement analysis data that represent the most relevant judgment criteria from a biomechanical point of view ([11], see Table 1). These parameters make it possible to differentiate between "better" and "worse" handspring performances. Gymnasts who perform better handsprings on vault show differences in the approach run, first flight phase, repulsion phase, second flight phase and landing phase. One can say that during the approach run, a higher initial velocity characterizes better handsprings on vault because the initial velocity determines the kinetic energy of the athlete [25]. The first flight phase is characterized by a higher amount of angular momentum and a shorter duration [7]. The repulsion phase is characterized by a support angle on the vaulting table close to 30 degrees, a shorter contact time on the vaulting table, a take-off angle close to 90 degrees, a larger moment of inertia about the somersault axis at take-off and higher horizontal and vertical velocities at take-off [6]. The second flight phase is characterized by a longer duration and consequently by a larger height of flight [7,25]. A better handspring performance on vault is furthermore characterized by a larger moment of inertia about the transverse axis during landing and by a larger flight distance [6].

Procedure

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 briefed about the general purpose and the procedure of the study except for the experimental manipulation of the springboard distance. In particular, the gymnast was told that she was taking part in a study on the kinematics of the handspring on the vault. Afterwards the gymnast's weight and height were measured and 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 the second phase the gymnast was asked to perform 15 handsprings on vault. When walking back to her starting point to the far edge of the running track, an instructed experimenter placed the springboard according to the individual experimental protocol for the gymnast: 1) either at her individual springboard distance (ISD), 2) 0.10 m closer to the leading edge of the vaulting table (ISD – 0.10 m), or 3) 0.10 m farther away from the leading edge of the vaulting table (ISD + 0.10 m) with regard to the individual springboard distance.

The third phase of the experiment took place after the 15 handsprings on vault were completed. First, a manipulation check was conducted in which the gymnast was asked if she had perceived any experimental manipulation during the second phase of the experiment. None of the gymnasts indicated that she had perceived an experimental manipulation. After the manipulation check the gymnast was told the specific purposes of the study together with the experimental manipulation of the springboard distance. The gymnast received 25 Euros as a reward for participation.

Data Analysis

A significance criterion of $\alpha = 5\%$ was established for all results reported. Prior to testing the main hypothesis, moderating effects of age were assessed using multivariate methods. There were no statistically significant moderating influences of age on the dependent variables. In order to assess differences between the three experimental conditions, separate univariate ANOVAs with repeated measures were calculated. Through the calculation of Holm's correction, the inflation of type I and type II errors was controlled [18]. Post-hoc analyses were carried out using Tukey's HSD post-hoc test because of its greater power and control for type II error inflation compared to other post-hoc tests. Cohen's f was calculated as an effect size for all F-values.

RESULTS

One of two different patterns of results was expected: If the position of the springboard is a relevant informational source, then parameters that are temporally or spatially related to the springboard should not differ between the three experimental conditions. Parameters of prior movement phases should differ as a function of the springboard position. If in turn the position of the springboard is not a relevant informational source, then parameters that are temporally or spatially related to the springboard should vary as a result of a manipulation of the springboard position. In addition, parameters of prior movement phases should be uninfluenced by a manipulation of the position of the springboard. We had no specific prediction on the effects of a manipulation of the remaining kinematic parameters of the handsprings on vault but additionally sought to explore this effect.

Summaries of the approach run and handspring kinematic measures are presented in Table 1. Manipulating the position of the springboard revealed significant effects ($p < .05$) on distance of wrists to the back edge of the vaulting table, angular momentum of the body during the first flight phase, phase duration of the first flight phase, phase duration of the repulsion phase, take-off angle, phase duration of the second

TABLE 1. PARTICIPANT'S KINEMATIC PARAMETERS (MEANS ± STANDARD ERRORS) OF THE HANDSPRINGS ON VAULT IN THE THREE EXPERIMENTAL CONDITIONS (ISD + 0.10 M, ISD NORMAL, ISD – 0.10 M) AS WELL AS STATISTICAL PARAMETERS OF THE SEPARATE ANOVAS

Movement Phase / Parameter	ISD + 0.10 m Mean ± SE	ISD Mean ± SE	ISD – 0.10 m Mean ± SE	*F*(2, 26)	*p*	Cohen's *f*
Run-up & Take-Off						
Distance of feet to leading edge on the springboard [m]	0.37 ± 0.02	0.36 ± 0.02	0.38 ± 0.02	0.469	.6310	0.19
Initial centre of mass velocity [m s^{-1}]	6.09 ± 0.10	6.05 ± 0.10	6.10 ± 0.10	2.795	.0802	0.46
First Flight Phase						
Distance of wrists to back edge of the vaulting table [m]	0.76 ± 0.04	0.72 ± 0.03	0.70 ± 0.03	14.202	.0001 *)	1.05
Angular Momentum [N m s]	100.67 ± 2.74	101.49 ± 3.38	105.04 ± 3.04	5.895	.0077 a)	0.67
Phase Duration [s]	0.30 ± 0.01	0.29 ± 0.01	0.28 ± 0.01	8.735	.0013 *)	0.82
Repulsion Phase						
Support Angle [°]	43.88 ± 1.92	44.67 ± 1.55	43.31 ± 1.94	0.838	.4437	0.25
Phase Duration [s]	0.24 ± 0.02	0.23 ± 0.02	0.22 ± 0.02	4.031	.0299 a)	0.56
Take-Off Angle [°]	95.62 ± 3.06	94.39 ± 2.94	91.48 ± 3.22	10.232	.0005 *)	0.89
Moment of Inertia at Take-Off [kg m^2]	17.50 ± 0.25	17.43 ± 0.28	17.37 ± 0.25	0.862	.4342	0.26
Second Flight Phase						
Phase Duration [s]	0.58 ± 0.02	0.58 ± 0.02	0.60 ± 0.02	6.840	.0041 *)	0.73
Angular Momentum [N m s]	72.71 ± 1.65	71.34 ± 2.25	69.60 ± 1.42	3.204	.0410 a)	0.53
Height of Flight [m]	0.09 ± 0.02	0.08 ± 0.02	0.10 ± 0.02	3.049	.0646	0.48
Landing						
Flight Distance [m]	1.14 ± 0.07	1.11 ± 0.08	1.16 ± 0.07	0.789	.4648	0.25
Moment of Inertia at Touch-Down [kg m^2]	16.25 ± 0.26	16.15 ± 0.29	16.06 ± 0.28	1.217	.3124	0.31

Note: *) Significant effect of Experimental Condition a) The effect of Experimental Condition became non-significant after applying Holm's correction.

flight phase and angular momentum of the body during the second flight phase. However, after applying Holm's correction, the effects of springboard position on angular momentum during the first and second flight phase as well as on phase duration of the repulsion phase became non-significant. Distance of feet to leading edge on the springboard, initial centre of mass velocity during the take-off phase, support angle during the repulsion phase, moment of inertia at take-off, height of flight, flight distance and moment of inertia at touch-down were not influenced by a manipulation of the springboard distance. Taking the results together, a smaller springboard distance to the front edge of the vaulting table resulted in a smaller distance of the hands to the back edge of the vaulting table, a shorter first flight phase, a take-off angle closer to 90° at the end of the repulsion phase and a longer phase duration of the second flight phase and vice versa. The placement of the feet on the springboard remained uninfluenced by a manipulation of the springboard distance.

The difference in foot placement during the approach run between the ISD + 0.10 m, ISD – 0.10 m and the ISD normal condition is presented in Figure 2. It was found that foot placement differed significantly in both the ISD – 0.10 m and the ISD + 0.10 m condition from the ISD normal condition in the third last, second last, last step (hurdle) and during touchdown on the springboard. Gymnasts placed their feet on average in the same position on the springboard, and adapted to the experimental manipulation of the springboard positioning during the last three steps of their approach run.

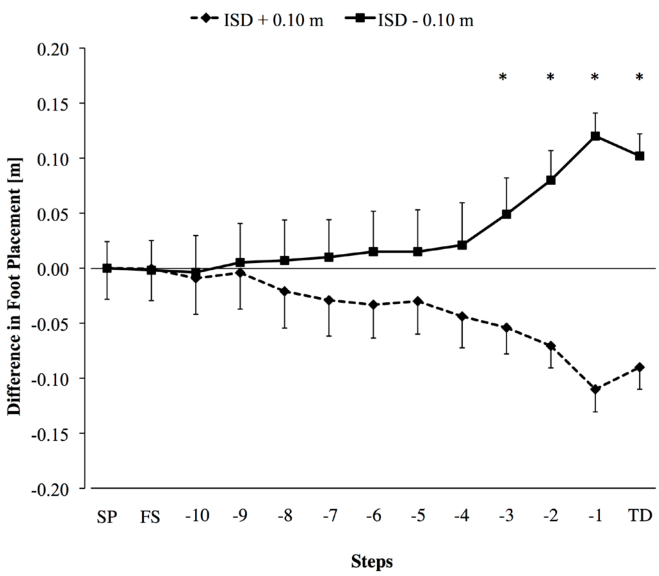

FIG. 2. DIFFERENCE IN FOOT PLACEMENT DURING THE APPROACH RUN (SP = STARTING POSITION, FS = FIRST STEP, TD = TOUCH-DOWN ON SPRINGBOARD). ISD – 0.10 M REFERS TO THE DIFFERENCE IN FOOT PLACEMENT BETWEEN THE NORMAL SPRINGBOARD DISTANCE CONDITION AND THE CONDITION WHERE THE SPRINGBOARD WAS PLACED 0.10 M CLOSER TO THE VAULTING TABLE. ISD + 0.10 M REFERS TO THE DIFFERENCE IN FOOT PLACEMENT BETWEEN THE NORMAL SPRINGBOARD DISTANCE CONDITION AND THE CONDITION IN WHICH THE SPRINGBOARD WAS PLACED 0.10 M FARTHER FROM THE VAULTING TABLE

DISCUSSION

Taking the results of the current study together, it becomes apparent that gymnasts utilize the position of the springboard as an informational source to control the approach run and the positioning of the feet during the take-off phase. This conclusion is consistent with the studies of Meeuwsen and Magill [19] and Bradshaw [4]. From the theory of direct perception we argue that visually perceiving the position of the springboard guides the approach run in gymnastics. An advantage of using vision in the approach run is that it may enable the gymnast to make small corrections in foot placement throughout the approach, which may occur due to intrinsic and extrinsic factors [5]. In this sense it may also enable the gymnast to adapt his/her approach run in every trial to accurately hit the springboard in order to perform the intended movement with an optimal movement quality.

However, setting the position of the springboard as well as the length of the approach run is still common training practice in gymnastics. Gymnasts typically start from a fixed distance with the same springboard-vaulting table distance. This implies that gymnasts perform a stereotyped approach run with a stride length that is consistent between trials. It is assumed that their feet will land at the same spot along the approach run and during the touchdown on the springboard after the hurdle, leading to a consistent handspring performance as well [24]. This, however, ignores the possibility that the approach run may be regulated in a continuous manner on the basis of visual information. As can be concluded from our study and the studies by Meeuwsen and Magill [19] as well as Bradshaw [4], the position of the springboard has a direct effect on movement regulation and gymnasts seem to adjust their approach run to accommodate the springboard position in a manner that best suits the circumstance of the situation [5].

The approach run represents an important component in vaulting because it determines the level of kinetic energy the gymnasts can utilize in later phases of the movement [6]. More specifically, a higher energy level generated by the approach run enables the gymnast to take off from the springboard with greater velocity, leading to a longer second flight phase [6]. A longer second flight phase is an important precondition to perform more complex skills [14]. It is furthermore a relevant judging criterion [11,25]. One could argue that regulating the approach run could lead to a reduction in initial centre of mass velocity, which in turn would lead to a worse handspring. However, as can be seen from our data, there was no effect of the experimental manipulation on initial centre of mass velocity, so the initial energy level was the same for the three experimental conditions.

The capacity to guide foot placement during the approach run to negotiate the springboard during the take-off phase may depend on the observer's ability to perceive angular velocity of the changing environment [15]. The perceptual threshold for perceiving angular velocity is thought to be about 1/12 degree per second [16], so that at certain distances the target may be perceived to be so small that it does not provide any relevant information to guide the timing of an interceptive action [15]. This could at least in part explain why the foot placement during the approach run is influenced significantly during the last three steps, because at this distance (approximately 7.12 m to the vaulting table) the perception of the springboard position is beyond the aforementioned perceptual threshold, and thus can provide relevant information to guide the approach run and the hurdle.

We want to highlight two limitations of this study that need to be taken into account: First, it was concluded that gymnasts use the position of the springboard as a relevant informational source in regulating the approach run and the handspring on vault in gymnastics. This conclusion assumes that a gymnast visually picks up the position of the springboard during the approach run. However, the gymnast's visual information pickup was neither manipulated nor measured in this study. Thus a subsequent study could incorporate the measurement of visual information pickup in the design. Furthermore, manipulating visual information pickup directly related to the position of the springboard (e.g., by using visual occlusion) could more specifically answer the question when the position of the springboard is perceived and when this perception is used to regulate the approach run.

Second, we manipulated the position of the springboard in steps of 0.10 m. One could argue that a stronger manipulation could lead to different effects on the approach run and/or handspring kinematics. A larger manipulation could potentially lead to a breakdown in regulating the approach run, such that gymnasts are not capable of performing the handspring any more. Gymnasts could furthermore become aware of the manipulation, which in turn could induce different visual information pickup, leading in turn to different regulation. However, it could be of interest to investigate the conditions under which the aforementioned result will occur. This could answer the question to which degree gymnasts are able to deal with varying springboard distances. This should be done while measuring gymnasts' visual information pickup in order to control for changes in visual information pickup that may occur as a result of larger manipulations of the springboard distance.

CONCLUSIONS

There are some practical consequences and implications that can be drawn from the current study. First, a shorter distance of the springboard to the front edge of the vaulting table resulted in better handspring performances. In particular, the take-off angle at the end of the repulsion phase was closer to 90° and the second flight phase was longer. A take-off angle closer to 90° and a longer second flight phase are significant predictors of judges' scores [25]. Therefore, it may be appropriate to shorten the springboard distance if the aim is to optimize the handspring temporarily. However, it could also be possible that after several attempts with a shorter springboard distance, the athlete adapts to the new springboard distance, falling back to the movement pattern suitable for the normal springboard distance [8]. Second, a stereotyped method of training may not equip the gymnast with the necessary experience to adjust for changing environments in training and competition. Therefore, the coach should encourage learners to practise the handspring on vault under varying conditions. This can easily be achieved by practising the approach run from different distances together with different positions of the springboard (see also [4], for more considerations on varying practice conditions in gymnastics vaulting).

We state that athletes regulate handsprings on vault on the basis of the (visually) perceived position of the springboard. Knowledge about relationships between informational sources in the environment and the resulting regulatory processes in athletes may help coaches to develop specific training programmes in order to optimize performance in complex skills.

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