Baltic Journal of Health and Physical Activity 2015;7(4):61-72
Journal of Gdansk University of Physical Education and Sport in Gdansk
e-ISSN 2080-9999

ORIGINAL

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

Task dependency of movement regulation in female gymnastic vaulting

Thomas Heinen [AE], Isabell Artmann [BC], Anja Brinker [CD], Marc Nicolaus [F]

Institute of Sports Science, University of Hildesheim, Germany

abstract

Background In gymnastics vaulting it is thought that gymnasts regulate their run-up on the basis of visually perceived environmental information, such as the position of the springboard, with the aim of an accurate foot placement on the springboard. The question, however, arises if these regulative processes found in gymnastics vaulting can be generalized to other tasks with similar demands but differing dynamics?

Material/Methods To answer this question, ten female gymnasts were asked to perform two target-directed gymnastics tasks that were similar in task demands but differed in task dynamics. When performing the two tasks, the position of the springboard was manipulated without the gymnast's awareness.

Results Results revealed that manipulating the position of the springboard had neither an effect on the distance of the hurdle, nor on the placement of the feet on the springboard during the reactive leap. The two parameters, however, clearly differed between experimental tasks. Additionally, regulation during run-up occurred on average one step earlier when performing the tucked leap on the balance beam.

Conclusions It can be concluded from the results that gymnasts exhibit a different movement behavior when performing tasks with similar demands but different dynamics, thereby integrating environmental information in the regulation of the run-up and the reactive leap from trial to trial.

Key words visual perception, environmental information, constraints, artistic gymnastics, complex skill performance

article details

Article statistics **Word count:** 4,525; **Tables:** 0; **Figures:** 3; **References:** 34

Received: September 2015; **Accepted:** November 2015; **Published:** December 2015

Full-text PDF: http://www.balticsportscience.com

Indexation: AGRO, Celdes, CNKI Scholar (China National Knowledge Infrastructure), CNPIEC, De Gruyter - IBR (International Bibliography of Reviews of Scholarly Literature in the Humanities and Social Sciences), De Gruyter - IBZ (International Bibliography of Periodical Literature in the Humanities and Social Sciences), DOAJ, EBSCO - Central & Eastern European Academic Source, EBSCO - SPORTDiscus, EBSCO Discovery Service, Google Scholar, Index Copernicus, J-Gate, Naviga (Softweco, Primo Central (ExLibris), ProQuest - Family Health, ProQuest - Health & Medical Complete, ProQuest - Illustrata: Health Sciences, ProQuest - Nursing & Allied Health Source, Summon (Serials Solutions/ProQuest, TDOne (TDNet), Ulrich's Periodicals Directory/ulrichsweb, WorldCat (OCLC)

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interest: Authors have declared that no competing interest exists.

Corresponding author: Thomas Heinen, University of Hildesheim, Institute of Sports Science, Universitaetsplatz 1, 31141 Hildesheim, Germany, Phone: +49 (0) 5121 / 883 – 11914, E-Mail: thomas.heinen@uni-hildesheim.de

INTRODUCTION

A basic, nevertheless important, skill in gymnastics is to perform a reactive leap on a springfloor, or a springboard, after a run-up. This skill is particularly needed in gymnastics vaulting or when performing mounts on uneven bars or a balance beam [1, 2]. For instance, in gymnastics vaulting it is thought that gymnasts regulate their run-up on the basis of (visually perceived) environmental information, such as the position of the springboard, with the aim of an accurate foot placement on the springboard during the subsequent reactive leap [3, 4]. Nevertheless, there are manifold tasks in gymnastics in which the aforementioned skill is needed, and the question arises if regulative processes found in gymnastics vaulting can be generalized to other tasks in gymnastics with similar demands but different dynamics? Therefore, the aim of this study was to analyze to what extent the position of the springboard is a relevant informational source in the performance of two tasks in gymnastics that are similar in task demands but different in task dynamics.

From recent theoretical approaches and empirical evidences one may argue that expert gymnasts perceive task-relevant environmental information directly and use that information to regulate their movements [3, 5, 6, 7]. During skill acquisition, gymnasts learn how sensory stimulation changes as a function of skill execution with respect to the environment, thereby developing specific contingencies between sensory stimulation and the (movement) requirements of a particular skill [7, 8]. In target-directed activity, such as when performing run-ups with subsequent leaps on the vault, it is likely that the vaulting apparatus provides relevant information that gymnasts use in order to regulate their movements [3, 9].

In this context, Meeuwsen and Magill [10] studied the run-up in gymnastics vaulting. The authors had six female gymnasts perform run-ups followed by a handspring vault, and run-throughs where no vaulting apparatus was present. An analysis of stride kinematics revealed differences in the standard deviation in the footfall position during the last two steps and the hurdle, when gymnasts performed a run-up with a subsequent handspring as compared to when gymnasts performed a run-through. Bradshaw [3] had five female gymnasts perform round-off entry vaults. An analysis of standard deviation of the footfall position during run-up revealed that regulation occurred on average two steps prior to the hurdle of the round-off. In addition, Heinen et al. [9] had fourteen female gymnasts perform handsprings on a vault while the position of the springboard was systematically manipulated without the gymnast's awareness. An analysis of movement kinematics of the run-up and the vault revealed that gymnasts placed their feet on average in the same position on the springboard when the position of the springboard varied ±10 centimeters without the gymnast's awareness. One may conclude from the above mentioned studies that the vaulting apparatus significantly constrains gymnast's movement behavior, thereby providing information that is used to regulate the run-up and the reactive leap in gymnastics vaulting (see also [4]).

Skill acquisition in gymnastics is thought to be specific to the sources of afferent information available, and gymnasts become attuned to the most useful information that can guide a given task [11, 12]. Once acquired, task execution is tightly coupled to the use of this information [13]. If execution of a task is tightly coupled to the use of particular information, then it should be likely that the use of this particular information can be generalized to tasks with similar demands. However, gymnastics tasks with similar demands but different dynamics may afford a different motor behavior [14, 15, 16]. For instance, Takei [15, 17, 18] analyzed the relationship between movement kinematics and judges' scores of the handspring, the handspring with a full turn, and the handspring with a forward somersault, respectively. When comparing the results of the three studies, it becomes obvious that the three tasks clearly differ in task dynamics, and therefore afford a different motor behavior. Similar patterns of results can be found when comparing gymnastics tasks with similar demands that are performed under changing environmental constraints. Čuk and Ferkolj [19] studied for instance changes in technique of handspring vaults with double forward somersaults performed on the vaulting horse and the vaulting table, and Takei, Dunn, and Blucker [20] compared high-scoring and low-scoring handsprings with double forward somersaults (see also [21, 22]). The results of both studies again confirm the argument that gymnastics tasks with similar demands but different dynamics differ in the afforded motor behavior.

Following the aforementioned argumentation the aim of this study was to analyze to what extent the position of the springboard is a relevant informational source in the performance of two gymnastics tasks with similar task demands but different task dynamics. Expert gymnasts were asked to perform two mounts with differing movement dynamics: 1) a straight leap to hang on uneven bars, and 2) a tucked leap to landing on both feet on a balance beam. Distances of the hurdle as well as the position of the toes during the run-up and the reactive leap were measured in both tasks. Regulation during run-up was calculated from the standard deviation in the footfall position (see [23]). The springboard position was manipulated without a gymnast's awareness in order to analyze the regulative function of the springboard position in both tasks. It was hypothesized that neither distance of the hurdle, nor distance of the toes to the back edge of the springboard varied as a function of manipulation of the springboard position. The two parameters, however, were thought to vary as a function of the experimental task. Regulation during run--up was additionally expected to vary between tasks because of the different task dynamics.

MATERIALS AND METHODS

PARTICIPANTS

N = 10 female gymnasts were recruited to participate in this study (Age = 14 ±2 years). Gymnasts reported an average training experience of 7.5 ±1.3 years with a weekly practice amount of 9.5 ±3.5 hours (Means ±SD). They reported to take part in National Championships and Regional Championships. Therefore, the gymnasts in this study could be characterized as experts concerning the experimental tasks of this study [24]. It was decided to recruit experts in order to ensure that they were already attuned to the environmental informational sources that guide their action [6]. Gymnasts were informed about the general procedure of the study, and they gave their written consent prior to the beginning of the study. The study was carried out according to the ethical guidelines of the university's local ethics committee. To ensure that gymnasts remained naïve to the experimental conditions, they were, however, not informed about the experimental manipulation of the position of the springboard (see Procedure).

TASKS AND INSTRUMENTS

Experimental Tasks. Gymnasts were asked to perform two different experimental tasks. The first experimental task was a straight leap, performed as a mount to hang on the upper bar of uneven bars (see Figure 1-a). The second experimental task was a tucked leap, performed as a mount to landing on both feet on a balance beam (see Figure 1-b).

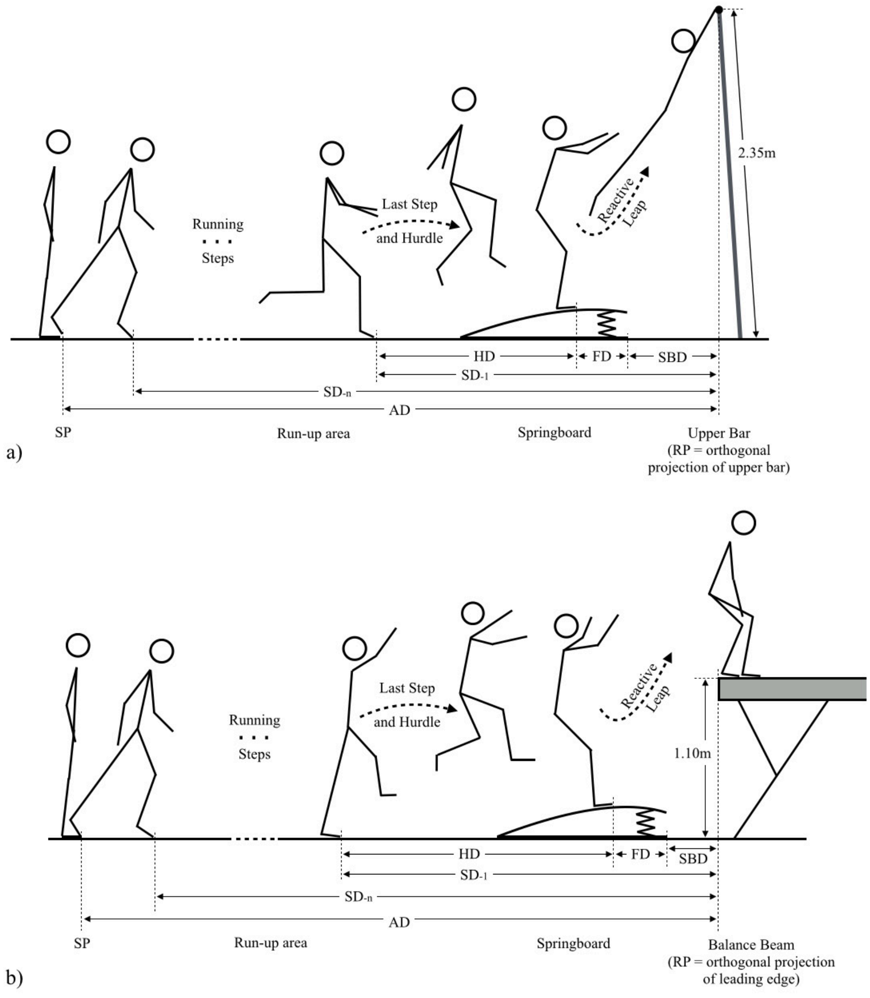

Fig. 1. Stick-figure sequence of the two experimental tasks: a) leap to hang on the upper bar of uneven bars, b) tucked leap to landing on both feet on a balance beam. (Note: SP = starting point, HD = distance of the hurdle movement, FD = distance of feet to the back edge of the springboard, SBD = springboard distance, SD = distance of the footfall position to reference point, RP = reference point)

The uneven bars and the balance beam were arranged and adjusted to match the competition guidelines for Women's Artistic Gymnastics [25]. For measuring purposes a reference point was defined for each apparatus. For the uneven bars the reference point was defined as the horizontal position of the orthogonal projection of the upper bar. For the balance beam the reference point was defined as the horizontal position of the orthogonal projection of the leading edge of the balance beam.

Both tasks were performed after a short run-up and with a certified springboard as a takeoff surface (1.20 meters long, 0.60 meters wide). It was decided to vary task dynamics indirectly by asking gymnasts to perform the two different mounts, but not by manipulating the task execution itself. This was done with the aim to study gymnasts' motor behavior in a natural setting with a high degree of ecological validity [26]. From an upright stance the gymnast passed over in a short run-up. Each gymnast started from her individual run--up distance. A hurdle movement succeeded the last step of the run-up. At the end of the hurdle movement the gymnast placed both feet on the springboard and performed a reactive leap, either with a straight or tucked body posture during a subsequent flight phase, depending on the experimental task to be performed. The straight leap ended with a hang on the upper bar of uneven bars, while the tucked leap ended with landing on both feet on a balance beam (see Figure 1). Both experimental tasks were similar in task demands, because in both tasks the gymnast performed a short run-up with a subsequent reactive leap from a springboard. Both tasks, however, differed in task dynamics, because when performing the tucked leap to landing on both feet on the balance beam, gymnasts usually exhibit a longer distance of the run-up.

Experimental Protocol. The gymnasts were asked to perform six trials in each of two conditions (one baseline condition and one experimental condition) in both experimental tasks for a total of 24 trials. The two experimental tasks were presented in a blockwise and randomized fashion for each gymnast. Experimental conditions were presented to the gymnasts in a pseudo-randomized order, with a rule of not presenting a condition more than twice in a row. It was decided to study gymnasts' motor behavior in a natural setting [26]. Therefore, the springboard was placed at the gymnast's individual springboard distance in relation to the reference point in the baseline condition ("BL" condition). The experimental condition of each block comprised a manipulation of the springboard distance in relation to the individual springboard distance. In particular, the springboard distance was extended 0.10 meters so that the springboard was placed 0.10 meters farther away from the reference point of each apparatus ("SBD+" condition). Each gymnast started the run-up from her individual run-up distance to the reference point. This distance was kept constant for each gymnast throughout the study.

It was decided to realize only one experimental condition with an extended distance and not with a reduced distance in each of the two experimental tasks mainly for two reasons. First, previous studies reported no qualitative differences when shortening or extending the springboard distance in gymnastics vaulting [9]. Therefore, one would expect the springboard to operate as an informational source anyway, independent of the number of experimental conditions. Second, one may observe that during the tucked leap, gymnasts often perform a flight phase in which the toes pass the leading edge of the balance beam in a rather short distance towards landing on both feet. Reducing the springboard distance could potentially lead to a reduction in the distance of the toes passing the leading edge of the balance beam during the tucked leap with the potential risk of colliding with the balance beam. In order to prevent such a situation, the springboard distance was extended in the experimental condition, but not shortened.

Kinematic Analysis. An optical movement analysis system was used to analyze the kinematics of the experimental tasks based on videotaped sequences of all task performances. One digital video camera was placed 25 meters away from and orthogonal to gymnast's movement plane of the uneven bars. The same was done with a second camera on the balance beam. The optical axes of both cameras were approximately 3.50 meters away from the reference point of each apparatus. Each camera recorded a visual field of approximately 7.20 meters width. The cameras had a sampling rate of 50 Hz and a spatial resolution of 1920 x 1080 pixels. They were calibrated to the movement plane of the gymnasts with the help of a 7.00 x 3.00 meter calibration frame (see also [27]). A frame rate of 50 Hz was deemed as sufficient because only spatial parameters were analyzed [28]. The horizontal positions of the toes at the starting point, during each step of the run-up, and during the initial contact on the springboard were analyzed. The positions were recorded using the movement analysis software utilius easyINSPECT [29].

To assess movement regulation of the reactive leap, two parameters were calculated: First, the horizontal distance from the toes during the last-step to the position of the toes of both feet when in contact with the springboard defines the distance of the hurdle movement. Second, the horizontal distance of the toes to the back edge of the springboard during the reactive leap defines the feet placement on the springboard. In order to assess movement regulation during the run-up, the standard deviation method was utilized [5, 23]. Therefore, standard deviations in the footfall position during the steps of the run-up were calculated across multiple trials. A peak in standard deviation with a subsequent decrease during the run-up indicates the use of visual information to adjust run-up kinematics relative to the springboard [3]. In addition, the length of the run-up was calculated as the horizontal distance of the positions of the toes at the starting point to the reference point of each apparatus. Finally, the amount of run-up steps was counted from the videotaped sequences of all task performances.

PROCEDURE

The study was conducted in three phases. All gymnasts were tested individually. In the first phase, the gymnast arrived at the gymnasium, was informed about the general purpose and procedure of the study, and completed the informed consent form. The gymnast was told that she was taking part in a study on the kinematics of two different skills in gymnastics. The gymnast was, however, not informed about the experimental manipulation of the springboard distance in order to remain naïve to the experimental manipulation. The gymnast was given an individual 30-minute warm-up phase. During warm-up, the gymnast was allowed three practice trials of the straight leap on uneven bars and the tucked leap on a balance beam in order to ensure that gymnast's motor system was adjusted to the apparatus set-up [30]. During practice trials, the springboard distance was set to the values of the BL condition, thereby reflecting gymnast's individual springboard distance. The second phase took place after the warm-up was completed.

In the second phase the gymnast was asked to perform 12 straight leaps performed as a mount on the uneven bars (Figure 1-a), and 12 tucked leaps performed as a mount on the balance beam (Figure 1-b). Both tasks were presented in a blockwise fashion. The fact whether the gymnast began with the straight leaps on uneven bars or tucked leaps on balance beam depended on chance. Both tasks were performed after a short run-up. When the gymnast was walking back to her individual starting point an instructed experimenter placed the springboard according to the individual experimental protocol for each gymnast: either (1) at the distance of the BL condition, or (2) at the distance of the SBD+ condition.

The third phase of the study took place after the 24 trials were completed. A manipulation check was conducted by asking a gymnasts if she had perceived any kind of experimental manipulation when performing the experimental tasks. None of the gymnasts responded having perceived an experimental manipulation. After the manipulation check, the gymnast was debriefed and received a gift as a reward for participation.

DATA ANALYSIS

A significance criterion of α = 5% was defined a priori for all reported results. Prior to testing the main hypotheses, differences in the length of the run-up, and the number of steps were evaluated between experimental tasks and experimental conditions. There was an obvious difference in the run-up length between the tasks (straight leap on uneven bars: 5.77 ±0.03 meters vs. tucked leap on balance beam: 6.87 ±0.03 meters [Means ±SE]), but not between experimental conditions. The same was true for the number of steps during the run-up (straight leap on uneven bars: 3.59 ±0.20 steps vs. tucked leap on balance beam: 4.82 ±0.24 steps [Means ±SE]), thereby indicating that both experimental tasks clearly differed in task dynamics.

In order to test the main hypotheses, separate 2 (Springboard Position: BL condition vs. SBD+ condition) × 2 (Experimental Task: straight leap to hang on uneven bars vs. tucked leap to landing on both feet on a balance beam) analyses of variance (ANOVAs) with repeated measures were calculated, including (1) the distance of the toes to the back edge of the springboard during the reactive leap, and (2) the distance of the hurdle as dependent variables. In a second step, the standard deviation on footfall position during the last four steps prior to the hurdle was calculated in order to analyze regulation during the run-up [3, 23]. Cohen's f was calculated as an effect size for all reported F-values [31, 32].

RESULTS

It was hypothesized that neither the distance of the hurdle, nor the distance of the toes to the back edge of the springboard varied as a function of the manipulation of the springboard position because of its informational, yet regulative role as in the performance of target-directed activity in complex skills in gymnastics. The two parameters, however, were thought to vary as a function of the experimental task due to the differing dynamics of both tasks. Regulation during run-up was additionally expected to vary between tasks because of the different task dynamics.

To test the main hypotheses, separate 2 (Springboard Position: BL condition vs. SBD+ condition) × 2 (Experimental Task: straight leap to hang on uneven bars vs. tucked leap to landing on both feet on a balance beam) ANOVAs were calculated while including (1) the distance of the toes to the back edge of the springboard during the reactive leap, and (2) the distance of the hurdle as dependent variables (Figure 2). Results of the ANOVAs revealed significant main effects of the Experimental Task on the distance of the toes to the back edge of the springboard during the reactive leap, $F(1, 9) = 38.713$, $p = .0002$, Cohen's $f = 2.074$, and on the distance of the hurdle, $F(1, 9) = 7.196$, $p = .0251$, Cohen's $f = 0.893$. There were neither additional main effects of Springboard Position on any of the dependent variables, nor additional interaction effects of Experimental Task × Springboard Position on any of the dependent variables (all $p > .05$).

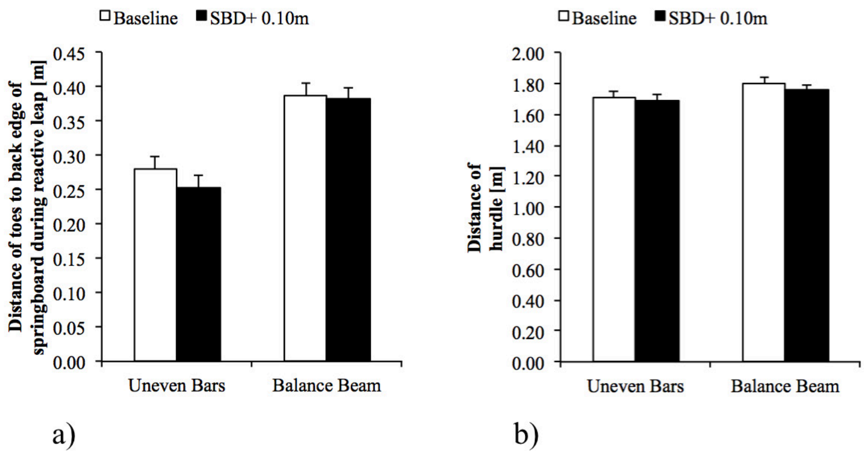

Fig. 2. a) Distance of toes to the back edge of the springboard during a reactive leap in both experimental tasks, and in the BL condition and the SBD+ condition (means ± standard error). b) Distance of the hurdle in both experimental tasks, and in the BL condition and the SBD+ condition (means ± standard error)

In order to assess movement regulation during the run-up, standard deviation on the footfall position during the last four steps prior to the hurdle was calculated. Results revealed the peak value in the third last step when performing the straight leap to hang on uneven bars in both the baseline condition and the SBD+ condition. When performing the tucked leap to landing on a balance beam, the peak occurred in the fourth last step in the baseline condition as well as in the SBD+ condition (Figure 3).

Taken together, results revealed that when performing the straight leap to hang on uneven bars, gymnasts exhibited on average a shorter distance of the toes to the back edge of the springboard (Figure 2-a), and a slightly shorter distance of the hurdle (Figure 2-b), compared to the tucked leap to landing on both feet on a balance beam. However, in the BL condition, gymnasts exhibited on average the same distance of the toes to the back edge of the springboard and the same distance of the hurdle, as compared to the SBD+ condition. Concerning the run-up, the peak in standard deviation of the footfall position was found to occur later during the run-up when performing the straight leap to hang on uneven bars as compared to when performing the tucked leap to landing on a balance beam (Figure 3).

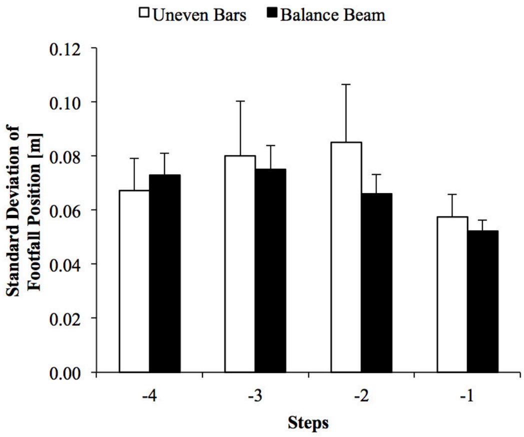

Fig. 3. Standard deviation in the footfall position during the last four steps of the run-up in both experimental tasks. Note that the peak in standard deviation occurred during the third last step when performing the tucked leap to landing on both feet on the balance beam while the peak occurred in the second last step when performing the straight leap to hang on uneven bars

DISCUSSION

The aim of this study was to analyze to what extent the position of the springboard is a relevant informational source in the performance of two gymnastics tasks that are similar in task demands but different in task dynamics. It was hypothesized that neither the distance of the hurdle, nor the distance of the toes to the back edge of the springboard varied as a function of manipulation of the springboard position. The two parameters, however, were thought to vary as a function of the experimental task due to the differing dynamics of both tasks. Regulation during run-up was additionally expected to vary between tasks because of the different task dynamics.

Results revealed that manipulating the position of the springboard without gymnast's awareness had neither an effect on the distance of the hurdle, nor on the placement of the feet on the springboard during the reactive leap. The results of this study are thus in line with results from studies of Meeuswen and Magill [10], Bradshaw [3] and Heinen et al. [9]. The position of the springboard clearly operates as relevant information in the regulation of the run-up and the reactive leap in the two experimental tasks. Therefore, one may conclude that in tasks that have similar demands, the role of particular information (here: springboard position) is invariant to the regulation of the movement. A direct perception of task-relevant environmental information may help gymnasts to make necessary adjustments during the run-up, which may occur due to extrinsic or intrinsic factors [5]. This in turn enables gymnasts to perform a reactive leap with a precise foot placement from trial to trial in order to perform the intended movement with an optimal movement quality. In addition, the idea of continuous regulation during the run-up at least partly neglects the assumption of a stereotyped run-up with a stride length that is strongly consistent between trials [1]. It can be concluded from this study, in line with the results of previous studies, that the position of the springboard constrains gymnasts' movement behavior in a way that gymnasts adjust their run-up that best suits the current circumstances of the situation.

In addition, the distance of the hurdle as well as the distance of the toes to the back edge of the springboard during the reactive leap were longer when performing the tucked leap to landing on both feet on a balance beam compared to the straight leap on uneven bars. Regulation during run-up occurred on average one step earlier when performing the tucked leap to landing on the balance beam. Thus, the results of the study confirm the argument that tasks with similar demands but different dynamics may afford a different motor behavior. When performing the tucked leap to landing on both feet on the balance beam, gymnasts made more steps, which in turn is likely to result in a higher velocity during run-up. A higher velocity during run-up usually results in a longer hurdle movement [33]. Bradshaw [3], Heinen et al. [9] and Meeuswen and Magill [10] found, for instance, that when gymnasts perform vaults from high run-up velocity they exhibit hurdle distances of more than 2.50 meters (cf. Figure 2). A longer hurdle may result in placing the feet closer to the middle of the springboard in order to utilize the flat spring mechanism of the springboard, which, however, only seems to operate at a particular touchdown impulse [34]. A higher run-up velocity may additionally afford an earlier regulation of the footfall position during the run-up, which in turn seems to be task-dependent. Comparing the results of this study with the results of the studies of Bradshaw [3], Heinen et al. [4, 9] supports this notion. Regulation occurred on average 7.83 meters from the rear of the takeoff board in the study of Bradshaw [3], and about 7.12 meters from the leading edge of the vaulting table in the study of Heinen et al. [9]. Taken together it seems obvious that gymnasts exhibit a different movement behavior when performing a task with similar demands but different dynamics, thereby integrating (changing) environmental information in the regulation of the run-up and the reactive leap from trial to trial.

LIMITATIONS

There are several limitations of this study and two specific aspects should be highlighted. First, the position of the springboard was manipulated 0.10 meters. A stronger manipulation could potentially lead to a breakdown in regulation, such that gymnasts may not be capable to encompass the manipulation on the springboard position, especially if the distance of the hurdle and the placement of the feet on the springboard are in principle invariant to a manipulation of springboard position. When realizing a stronger manipulation, gymnasts could become aware of the manipulation, which in turn could completely alter their natural movement behavior. It could, however, be of interest under which conditions this is likely to occur because it could answer questions concerning gymnast’s regulative capacity when dealing with varying springboard distances in different tasks. Second, gymnasts were asked to perform two tasks in which the springboard was used as a takeoff surface. Gymnasts, however, also perform reactive leaps after run-ups on the floor and on a balance beam. Therefore, one could speculate about regulatory processes when performing skills that are similar in task dynamics, but different in task demands, such as when performing a forward somersault on the floor as compared to when performing a forward somersault on a balance beam. Subsequent studies could therefore target the regulatory role of differing task demands in tasks that are similar in dynamics under varying environmental information.

CONCLUSION

There is at least one practical consequence of this study. Taken the theoretical background as well as the results of this study together, it can be stated that young gymnasts should be encouraged to systematically practice their ability to use visual information during the run-up in gymnastics tasks. This could lead to the acquisition of differentiated contingencies between sensory stimulation and the movement requirements of tasks that are similar in demands but different in dynamics. The development of such differentiated contingencies may enable the gymnast to cope with changing situations, such as when being in a competition or when dealing with different kinds of springboards.

It can be concluded that the use of environmental information in the regulation of run-ups with subsequent reactive leaps can be generalized to gymnastics tasks with similar demands but different dynamics, thus affording a different motor behavior.

REFERENCES

[1] Arkaev L., Suchilin N. How to create champions. Oxford UK: Meyer & Meyer Sports; 2004.

[2] Velićković S, Petković D, Petković E. A case study about differences in characteristics of the run-up approach on the vault between top-class and middle-class gymnasts. Sci Gym J. 2011;3(1):25-34.

[3] Bradshaw EJ. Target-directed running in gymnastics: a preliminary exploration of vaulting. Sport Biomech. 2004;3(1):125-144.

[4] Heinen T, Vinken PM, Jeraj D, Velentzas K. Movement regulation of handsprings on vault. Res Q Exer Sport. 2013;84:68-78.

[5] Bradshaw EJ, Sparrow WA. Effects of approach velocity and foot-target characteristics on the visual regulation of step length. Hum Mov Sci. 2001;20(4-5):401-426.

[6] Raab M, de Oliveira RF, Heinen T. How do people perceive and generate options? In: Raab, M, Hekeren H, Johnson JG, editors. Progress in brain research: Vol. 174. mind and motion: The bidirectional link between thought and action. Amsterdam NL: Elsevier; 2009, 49-59.

[7] Warren WH. The dynamics of perception and action. Psych Rev. 2006;113(2):358-389.

[8] O'Regan JK, Noë A. A sensorimotor account of vision and visual consciousness. Behav Brain Sci. 2001;24(5):973-1031.

[9] Heinen T, Jeraj D, Thoeren M, Vinken PM. Target-directed running in gymnastics: the role of the springboard position as an informational source to regulate handsprings on vault. Biol Sport. 2011;28(4):215-221.

[10] Meeuwsen H, Magill RA. The role of vision in gait control during gymnastics vaulting. In Hoshizaki TB, Salmela JH, Petiot B, editors. Diagnostics, treatment and analysis of gymnastic talent. Montreal Canada: Congres Scientifique de Gymnastique de Montreal, Inc.; 1987, 137-155.

[11] Mackrous I, Proteau L. Specificity of practice results from differences in movement planning strategies. Exp Brain Res. 2007;183(2):181-193.

[12] Withagen R, Michaels CF. The role of feedback information for calibration and attunement in perceiving length by dynamic touch. J Exp Psych Human. 2005;31(6):1379-1390.

[13] Montagne G, Cornus S, Glize D, Quaine F, Laurent M. A perception-action coupling type of control in long jumping. J Mot Behav. 2000;32(1):37-42.

[14] Cormie P, Sands WA, Smith SL. A comparative case study of Roche vaults performed by elite male gymnasts. Technique. 2004;24(8):6-9.

[15] Takei Y. Techniques used by elite male gymnastics performing a handspring vault at the 1987 Pan American Games. Int J Sport Biomech. 1989;5:1-25.

[16] Takei Y, Kim EJ. Techniques used in performing the handspring and salto forward tucked vault at the 1988 Olympic Games. J Appl Biomech. 1990;6(2):111-138.

[17] Takei Y. Techniques used in performing handspring and salto forward tucked in gymnastics vaulting. Int J Sport Biomech. 1988;4:260-281.

[18] Takei, Y. Three-dimensional analysis of handspring with full turn vault: deterministic model, coaches' beliefs, and judges' scores. J Appl Biomech. 1998;14:190-210.

[19] Čuk I, Ferkolj SM. Changes in technique of handspring double salto forward tucked performed on horse and vaulting table. Acta Kinesiologiae Universitatis Tartuensis. 2008;13:20-30.

[20] Takei Y, Dunn JH, Blucker E. Techniques used in high-scoring and low-scoring 'roche' vaults performed by elite male gymnasts. Sport Biomech. 2003;2(2):141-162.

[21] Ferkolj M. A kinematic analysis of the handspring double salto forward tucked on a new style of vaulting table. Sci Gym J. 2010;2(1):35-48.

[22] Irwin G, Kerwin DG. The influence of the vaulting table on the handspring front somersault. Sport Biomech. 2009;8(2):114-128.

[23] Lee DN, Lishman JR, Thomson JA. Regulation of gait in long jumping. J Exp Psychol Human. 1982;8(3):448-459.

[24] Chi MTH. Two approaches to the study of experts' characteristics. In Ericsson KA, Charness N, Feltovich PJ, Hoffman RR, editors. The Cambridge Handbook of Expertise and Expert Performance. Cambridge UK: Cambridge University Press; 2006, 21-30.

[25] FIG [Fédération Internationale de Gymnastique]. 2013 Code of points: women's artistic gymnastics. [Available at http://www.fig-docs.com/Media/Codes%20of%20Points%202013%20-%202016/WAG/2013-2016%20WAG%20CoP.pdf] [Accessed June 5, 2015]

[26] Vickers JN. Perception, cognition, and decision training: the quiet eye in action. Champaign IL: Human Kinetics; 2007.

[27] Berg WP, Wade MG, Greer NL. Visual regulation of gait in bipedal locomotion: Revisiting Lee, Lishman, and Thomson (1982). J Exp Psychol Human. 1994;20(4):854-863.

[28] Prassas S, Kwon YH, Sands WA. Biomechanical research in artistic gymnastics: a review. Sport Biomech. 2006;5(2):261-291.

[29] CCC-Software. utilius easyINSPECT. Markkleeberg, Germany; 2008.

[30] Enoka RM. Neuromechanics of human movement (3rd ed.). Champaign IL: Human Kinetics; 2002.

[31] Ludbrook J. Multiple comparison procedures updated. Clin Exp Pharmacol P. 1998;25(12):1032–1037.

[32] O'Keefe DJ. Colloquy: Should familywise alpha be adjusted? Against familywise alpha adjustment. Hum Commun Res. 2003;29:431-447.

[33] Dainis A. A model for gymnastics vaulting. Med Sci Sport Exer. 1981;13(1):34-43.

[34] Sano S, Ikegami Y, Nunome H, Apriantono T, Sakurai S. The continuous measurement of the springboard reaction force in gymnastics vaulting. J Sport Sci. 2007;25(4):381-391.

Cite this article as:
Heinen T, Artmann I, Brinker A, Nicolaus M. Task dependency of movement regulation in female gymnastic vaulting. Balt J Health Phys Act. 2015; 7(4):61-72.