MANUAL GUIDANCE IN GYMNASTICS: A CASE STUDY

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Abstract

Although the use of manual guidance in gymnastics is widely spread, little is known about the effects of this technique on movement kinematics. The goal of this case study was to evaluate the effects of two manual guidance procedures on movement kinematics of a back handspring and a back tuck somersault following a round-off on the floor. Based on assumptions of high-level coaches it was predicted that the sandwich-grip would have different effects on movement kinematics in both skills than the iliac crest/thigh-grip. We analyzed performance of n = 6 female gymnasts in the two skills with and without guidance. Manual guidance had significant effects on different kinematic parameters in both skills. From our results we concluded, that the sandwich-grip should be applied in the first instance if the coach's interest is to optimize the angular momentum about the somersault axis and the second flight phase in the back handspring. The optimal guidance procedure in the round-off back tuck somersault routine would be a mixture of both, the sandwich-grip and the iliac crest/thigh-grip.

Keywords: *sandwich-grip, iliac crest/thigh-grip, movement kinematics, back handspring, back tuck somersault.*

INTRODUCTION

A technique frequently used in teaching complex skills in gymnastics is guidance, which means physically, verbally, or visually directing a learner through a task performance (Schmidt & Lee, 2005; Wulf & Shea, 2002). Although gymnasts encounter all guidance types regularly throughout their career, manual guidance (also referred to as "spotting") is thought to be essential during the learning process in gymnastics (Arkaev & Suchilin, 2004; Dowdell, 2010). The learner is assisted by the hands of the coach who pushes or pulls the learner through the sequence or through specific parts of the task (Knudson & Morrison, 2002). Because guidance can be adjusted according to the learner's stage of skill and the experience of the coach, it is an adaptive procedure providing physical support, assistance, or assurance as a result of the physical force the coach applies to the learner (Arkaev & Suchilin, 2004).

When *supporting* the learner, the coach applies forces on the learner that most often influence the mechanics of the movement. When *assisting* the learner, the forces applied are reduced and the hands of the coach are in slight contact with the learner. When the learner progresses in skill execution, guidance is mainly used to *assure* the skill at hand, like for instance stabilizing specific phases of a skill or taking appropriate action in case of an unplanned fall (Sands, 1996). The transitions between the three forms of manual guidance are smooth, depending on the level of mastering the skill and the experience of the coach.

Guidance in daily gymnastics training is normally used in a way that the coach tries to *optimize* the current movement of the gymnast in an attempt to reduce errors or to dispel the learner's fear (Arkaev & Suchilin, 2004; Schmidt & Lee, 2005). Using guidance to optimize the current movement will, by definition, have strong effects on movement kinematics because the coach will either support or assist the gymnast. Because less is known about these effects in complex skills in gymnastics, the aim of this study was to evaluate the effects of two manual guidance procedures on movement kinematics in two floor routines, a round-off with a back handspring, and a round-off with a back tuck somersault.

The effects of manual guidance on performance in the acquisition and transfer of motor skills can be explained by the *specificity of learning hypothesis* (Schmidt & Lee, 2005). According to this hypothesis, the best learning experiences are those that approximate the movement components, including for instance sensory feedback of the target skill. It is suggested, that motor learning involves a sensorimotor representation, which integrates central processes and motor components with sensory information available during practice (Proteau, 1992; Mackrous & Proteau, 2007). This representation results in specificity during transfer when guidance is removed, such that performance is optimized when the conditions during transfer match the conditions during practice.

Work on the effects of either physical or manual guidance in more complex skills in gymnastics has been done by McAuley (1985), Heinen, Pizzera and Cottyn (in press), and Rosamond and Yeadon (2009). In McAuley's experiment, 39 participants learned a dive forward roll mount onto a balance beam from a springboard in one of three conditions (aided modeling, unaided modeling and control). Participants were given verbal feedback and manual guidance in the aided modeling group but no manual guidance in the other two groups. McAuley (1985) could show that guided participants enhanced their movement quality when guidance was removed. However, the author did not assess kinematic parameters of the movement.

Heinen et al. (in press) had 26 gymnasts learn the cartwheel on the balance beam and another 26 gymnasts learn the forward somersault as a dismount from the balance beam under either a guidance condition or a no-guidance condition. The authors could show that manual guidance had a significant effect on performance in the somersault but not in the cartwheel. This effect manifests itself in later steps of a methodical progression and in a transfer test. However, the authors assessed performance by means of an expert rating but did not analyze kinematic parameters of the two skills.

Rosamond and Yeadon (2009) constructed a training aid to assist the learning process of a backward handspring in gymnastics. The authors had one novice gymnast learn the back handspring and another novice gymnast relearn the skill with the training aid. The authors state, that gymnast A progressed faster in acquiring the back handspring than the rest of the training group and gymnast B showed an observable improvement in technique that occurred also at a faster rate that the rest of the training group. The training aid made gymnasts increase their take-off velocity leading to an optimized trajectory of the center of mass during the flight phase of the back handspring, indicating a short-term effect on movement kinematics. Despite that Rosamond and Yeadon (2009) observed the short-term effects of the training aid, the authors did not provide further kinematic parameters of the back handspring.

Taken the aforementioned results together, one may conclude that manual guidance can be beneficial when used with complex motor skills in gymnastics. The current research suggests that the guidance procedure used may have constrained the optimal number of degrees of freedom necessary for learners, providing them with task-specific sensory information early in practice, leading to better performance in transfer and retention (Proteau, 1992). However, given that guidance is a highly adaptive procedure that can potentially change different kinematic parameters depending on “how” the participant is guided, different guidance procedures could therefore lead to different changes in movement kinematics. These changes could in turn lead to differences in the learning or relearning of the skill. We argue that one need to know the short-term effects of different guidance procedures on movement kinematics before applying them in gymnastics.

We therefore analyzed the effect of two different guidance procedures on movement kinematics in the two routines round-off back somersault, and round-off back handspring on the floor. We have chosen the two routines for two reasons. First, both routines are essential in the learning process in competitive and recreational gymnastics. In recreational gymnastics, both routines are often –at least in Germany– an important part of the compulsory floor routines. In competitive gymnastics, an optimal technique in both routines is a necessary requirement for the development of more complex skills such as a double back somersault. Second, both routines can be guided with the same two guidance procedures, allowing for a comparison of the effect of the two procedures on movement kinematics of the two different routines.

We selected the “sandwich-grip” and the “iliac crest/thigh-grip” as guidance procedures (see method section). In order to generate hypothesis on the effects of manual guidance on movement kinematics, we asked two independent national level coaches (FIG level III license in women’s artistic gymnastics) on how both procedures might influence different kinematic parameters. From the interviews of the coaches we hypothesized that both guidance procedures should neither change the time-structure, the somersault angle, nor the moment of inertia about the somersault axis. The iliac crest/thigh-grip should have a stronger effect on angular momentum and the sandwich-grip should have a stronger effect on the velocity of the center of mass. Regarding the round-off back somersault, we assumed, that the two guidance procedures should neither influence the somersault angle, the moment of inertia about the somersault axis nor the angular momentum. Both guidance procedures should have a significant effect on the time-structure and the velocity of the center of mass.

METHODS

Participants

Participants were n = 6 female gymnasts from a local gymnastics club, aged 16 to 22 years, with a mean age of 18.2 years (SD = 2.0 years). They had a minimum of six years of gymnastics experience with regular practice and participation in regional championships. All participants were informed about the purpose and the procedure of the experiment and provided written informed consent prior to participation. The experiment was carried out according to the ethical guidelines of the German Sport University Cologne. There were no injuries during the experiment.

Tasks and Materials

Experimental Tasks and Guidance Procedures. The first experimental task was a round-off with a following back handspring and a subsequent straight jump on the floor (Figure 1a). The second experimental task was a round-off with a following back tuck somersault on the floor (Figure 1b). Both tasks were performed from a short run-up, as the participating gymnasts would perform them in their daily training.

Manual guidance was provided by a highly trained female gymnastics coach who had over 15 years of experience in providing guidance to gymnasts of different age and skill levels. We instructed the coach to provide manual guidance on an optimal level for each gymnast, depending on her current mastery level of the task at hand. We chose two different guidance procedures, (1) the “sandwich-grip”, and (2) the “iliac crest/thigh-grip” (Gerling, 2009).

This was done because both are the most common and well-established procedures when guiding the back handspring or the somersault in both, recreational and competitive gymnastics.

When using the sandwich-grip on the round-off back handspring, the first hand of the coach touches the gymnast's belly during the round-off whilst the second hand touches the iliac crest during the first support. The second hand stays on the iliac crest throughout the whole routine and the first hand leaves the belly in the middle of the first flight phase. It touches the belly again when the gymnast takes-off the floor prior to the second flight phase. The first hand then stays on the belly until the end of the routine. When using the iliac crest/thigh grip on the round-off back handspring routine, the first hand of the coach touches the gymnast's iliac crest during the transition from first support to the first flight phase and stays on the iliac crest until the end of the routine. The second hand touches the back of the thigh immediately after the gymnast takes-off to the first flight phase. The hand leaves the thigh prior to touch-down to second support (see Figure 2).

When using the sandwich-grip on the round-off back somersault, the first hand of the coach touches the belly of the gymnast already during the round-off, whilst the second hand touches the iliac crest during the support phase. The first hand stays on the belly until the gymnast has landed the somersault. The second hand leaves the gymnast's iliac crest immediately before he or she achieves the tucked position and touches the iliac crest again immediately before touch-down of the somersault. When using the iliac crest/thigh-grip on the round-off back somersault, the first hand of the coach touches the iliac crest during the transition from the support phase to the flight phase. The second hand touches the back of the thigh as soon as the gymnast has left the floor. The first hand stays on the iliac crest until the gymnast has landed the somersault. The second hand leaves the thigh immediately before the gymnast achieves the tucked position (see Figure 2).

Because we could not refer to any existing research to generate hypothesis on the effects of manual guidance on movement kinematics, we asked two independent national level coaches (FIG level III license in women's artistic gymnastics) on how both procedures might influence different kinematic parameters. With the help of an independent biomechanist and a top-level gymnastics coach, we chose five categories of kinematic parameters from the movement analysis data that represent the most relevant criteria from a biomechanical point of view. These categories were (1) the time-structure, (2) the velocity of the center of mass, (3) the somersault angle, (4) the moment of inertia about the somersault axis, and (5) the angular momentum about the somersault axis in both routines. These parameters can be used to model gymnastic performance (Knoll, 1999). They can furthermore be used to analyze gymnastic performance in terms of estimating the achievement of the movement goals.

The *time structure* is defined by the relative durations of the support and flight phases as well as distinct events, like take-off or touch-down during these phases. The *velocity of the center of mass* describes the directional change of the center of mass in horizontal and vertical direction. The *somersault angle* is a reliable criterion for the global orientation of the gymnast's body with regard to the horizontal. It was calculated as the angle between the line that joins the middle of the shoulders with the middle of the knees and the horizontal (Brüggemann, Cheetham, Alp & Arampatzis, 1994; Yeadon, 1990). The *moment of inertia* about the somersault axis was used as an indicator of the gymnast's posture. We calculated the moment of inertia about the transverse axis for each video frame following the suggestions by Hay, Wilson, and Dapena (1977) from the horizontal and vertical coordinates of 8 points of a 7-segment model of the human body. The *angular momentum* determines the amount of rotation and was also calculated following the suggestions of Hay et al. (1977). The values of the moments of inertia and the angular momentum were normalized to a body mass of 55 kg and a height of 1.60 m in order to permit comparison among all participants in all conditions (cf., Knoll, 1999; Kwon, 1996). All parameters were calculated with regard to distinct events in the time structure of the two routines (cf., Figure 1).

Regarding the round-off back handspring, both coaches agreed, that both guidance procedures should neither change the time-structure, the somersault angle, nor the moment of inertia about the somersault axis. They hypothesized, that the iliac crest/thigh-grip should have a stronger effect on angular momentum and the sandwich-grip should have a stronger effect on the velocity of the center of mass. Regarding the round-off back somersault, both coaches assumed, that the two guidance procedures should neither influence the somersault angle, the moment of inertia about the somersault axis nor the angular momentum. Both guidance procedures should have a significant effect on the time-structure and the velocity of the center of mass.

Movement Analysis System. An optic movement analysis system was used to determine the movement kinematics on the basis of video sequences of all performances. One digital video camera with a sampling rate of 300Hz was placed 15 meters away from the tumbling track and orthogonal to the movement direction of the gymnasts. The horizontal and vertical coordinates of 8 points (body landmarks) defining a 7-segment model of the human body (cf., Davlin, Sands & Shultz, 2004) were recorded for each frame using the movement analysis software WINanalyze 3D (Mikromak, 2008). We applied a digital filter (cut-off frequency = 6 Hz) for data smoothing and calculated a mean temporal error of ±0.0033 s and a mean spatial error of ±0.006 m. Body-segment parameters were calculated on the basis of the individual anthropometric properties of each participant (Yeadon & Morlock, 1989). To evaluate the reliability of the 7-segment model, we calculated the vertical acceleration of one gymnasts' center of mass in the after flight of a somersault sequence that was recorded with the same camera setup as mentioned above. Because the vertical acceleration should represent the gravitational acceleration, it is seen as a reliable indicator to evaluate kinematic data (Enoka, 2002). We calculated a value of $g = -(9.807 \pm 0.006)$ m/s² for vertical acceleration, which was not significantly different from the conventional standard value of $g = -9.81$ m/s², $t(5) = 0.72$, $p = .50$.

Procedure

The study was conducted in three phases. In the first phase, gymnasts arrived at the gymnasium and completed the informed consent form. In the second phase, gymnasts were asked to individually warm-up and prepare for floor exercises, as they would do in a normal training session. At the end of the warming-up, the gymnasts were asked to perform the two routines three times without guidance. In the third phase, gymnasts were asked to perform the round-off back handspring routine six times without guidance, and 12 times with manual guidance. Of these 12 trials, six trials were guided with the sandwich-grip and the remaining 6 trials were guided with the iliac crest/thigh-grip. The two guidance conditions were presented in a different order for each participant to control for sequence effects. Manual guidance was provided on an optimal level for each gymnast, depending on her current mastery level of the task at hand. All 18 performances of each gymnast were videotaped. Gymnasts could rest at will.

Data Analysis

A significance criterion of $\alpha = 5\%$ was established for all results reported. We conducted separate univariate analyses of variance (ANOVAs) with Manual Guidance as categorical predictor, including the key kinematic parameters as dependent variables. Post-hoc analyses were carried out using the Tukey's HSD post-hoc test. Cohen's f was calculated as an effect size for all *F* values higher than 1. To control for the inflation of Type I and II errors, we applied Holm's correction (Lundbrook, 1998). Reliability for each kinematic variable (Cronbach's alpha) was between .89 and .98. No significant differences were found between trials. Therefore all trials in each condition were averaged for further data analysis.

RESULTS

Effects of Manual Guidance on the Round-off Back Handspring Routine.

Together with two independent national level coaches, we assumed, that both guidance procedures should neither change the time-structure, the somersault angle, nor the moment of inertia about the somersault axis. Furthermore, we hypothesized, that the iliac crest/thigh-grip should have a stronger effect on angular momentum and the sandwich-grip should have a stronger effect on the velocity of the center of mass.

We found a significant effect of manual guidance on horizontal take-off velocity after second support (p = .0001, f = 1.64), vertical take-off after second support (p = .002, f = 1.44), somersault angle at touch-down to third support, (p = .0002, f = 1.49), and somersault angle at take-off after third support, (p = .04, f = 0.72). We found additional effects of manual guidance on moment of inertia at touch-down to third support, (p = .0008, f = 1.25), and angular momentum during the first flight phase (p = .001, f = 1.27). There was a small tendency for rejecting the null hypothesis for the effect of Manual Guidance on somersault angle at touch-down to second support (p = .06, f = 0.67, see Figure 3). The effect of manual guidance on somersault angle at take-off after third support became non significant after applying Holm's correction. However, the effects of Manual Guidance on somersault angle at touch-down to second support and on somersault angle at take-off after third support were large according to Cohen's (1988) classification, such that the effects seems to be of practical relevance although they were not significant.

Gymnasts exhibited a larger horizontal take-off velocity, a larger vertical take-off velocity, a larger somersault angle at touch-down to third support, and a larger moment of inertia at touch-down to third support when guided with either the sandwich-grip or the iliac crest/thigh-grip compared to the no-guidance condition. Gymnasts showed a larger angular momentum about the somersault axis during the first flight phase when guided with the sandwich-grip but not when guided with the iliac crest/thigh-grip.

Effects of Manual Guidance on the Round-off – Back Tuck Somersault Routine.

Together with two independent national level coaches, we assumed, that both guidance procedures should neither influence the somersault angle, the moment of inertia about the somersault axis nor the angular momentum. We furthermore hypothesized, that both guidance procedures should have a significant effect on the time-structure and the velocity of the center of mass

We found a significant effect of manual guidance on flight time (p = .0007, f = 0.79), horizontal take-off velocity (p = .004, f = 1.04 , vertical take-off velocity (p = .0002, f = 0.82), somersault angle at touch-down after round-off, (p = .001, f = 0.41), somersault angle at touch-down after the somersault (p = .004, f = 0.73), the moment of inertia during touch-down after the somersault (p = .001, f = 0.76). There was a tendency for rejecting the null hypothesis for the effect of Manual Guidance on angular momentum during the somersault (p = .09, f = 0.52, see Figure 4). However, the effect of manual guidance on angular momentum during the somersault was large according to Cohen's (1988) classification, such that the effect seems to be of practical relevance although it was not significant. We acknowledge that the vertical take-off velocity determines the height of flight and present this parameter here for completion purposes but did not integrate it in our statistical analyses. Compared to the no-guidance condition (Δh = 0.55 ± 0.02), gymnasts exhibited a higher flight phase in both guidance conditions (sandwich-grip: Δh = 0.67 ± 0.02 m, iliac crest/thigh-grip: Δh = 0.68 ± 0.02 m).

Gymnasts exhibited longer flight times, as well as larger vertical take-off velocities, smaller horizontal take-off velocities, and a larger moment of inertia at touch-down after the somersault when guided with either the sandwich grip or the iliac crest/thigh-grip. Gymnasts showed higher values for the somersault angle at touchdown after round-off when guided with the sandwich grip and a larger somersault angle at touch-down after the somersault when guided with the iliac crest/thigh-grip as compared to the no-guidance condition.

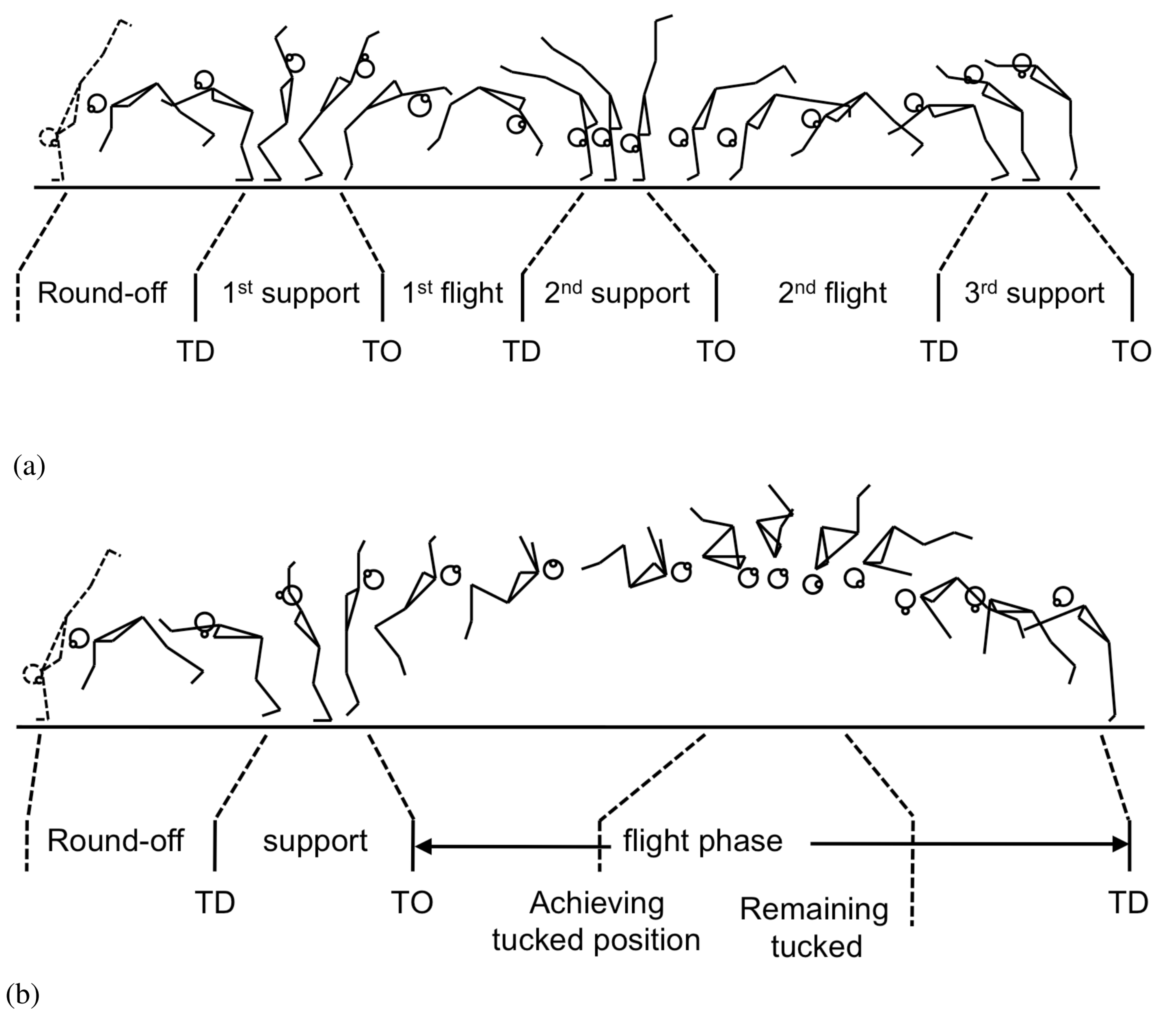
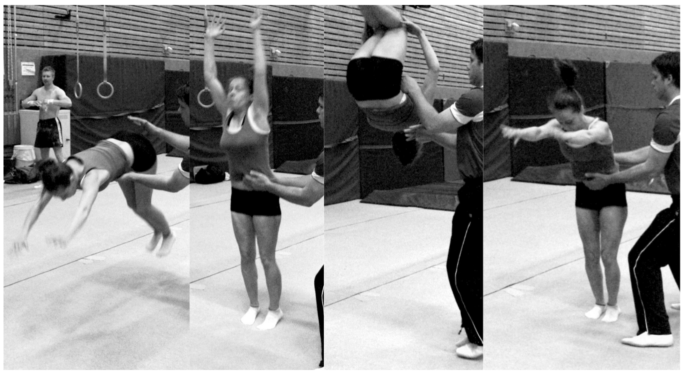


Figure 1. *Stick-figure sequence and definition of corresponding movement events and phases of the two routines round-off back handspring (a) and round-off somersault (b). TD = touch-down, TO = take-off. Key kinematic parameters were calculated with regard to distinct events in the time structure of the two routines.*


(a)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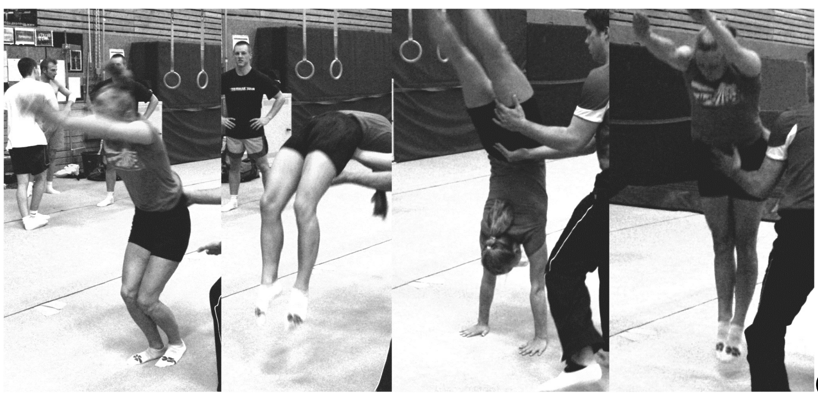
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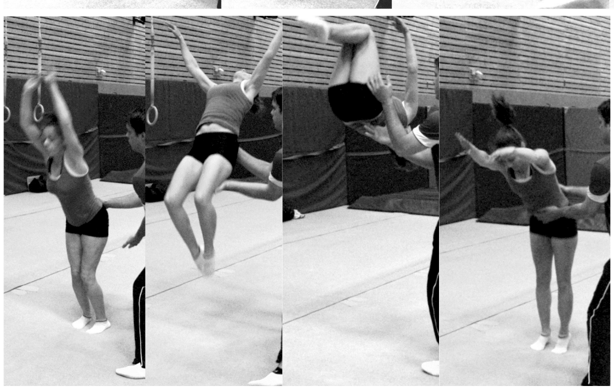

(d)

Figure 2. *Picture sequence to illustrate the two techniques to guide the back-handspring with (a) the sandwich-grip and (b) the iliac crest/thigh-grip, and the somersault with (c) the sandwich-grip and (d) the iliac crest/thigh-grip. Note: To ensure anonymity of the participants in our study, the coach and the gymnasts on the picture sequence are different from the ones who participated in our study.*

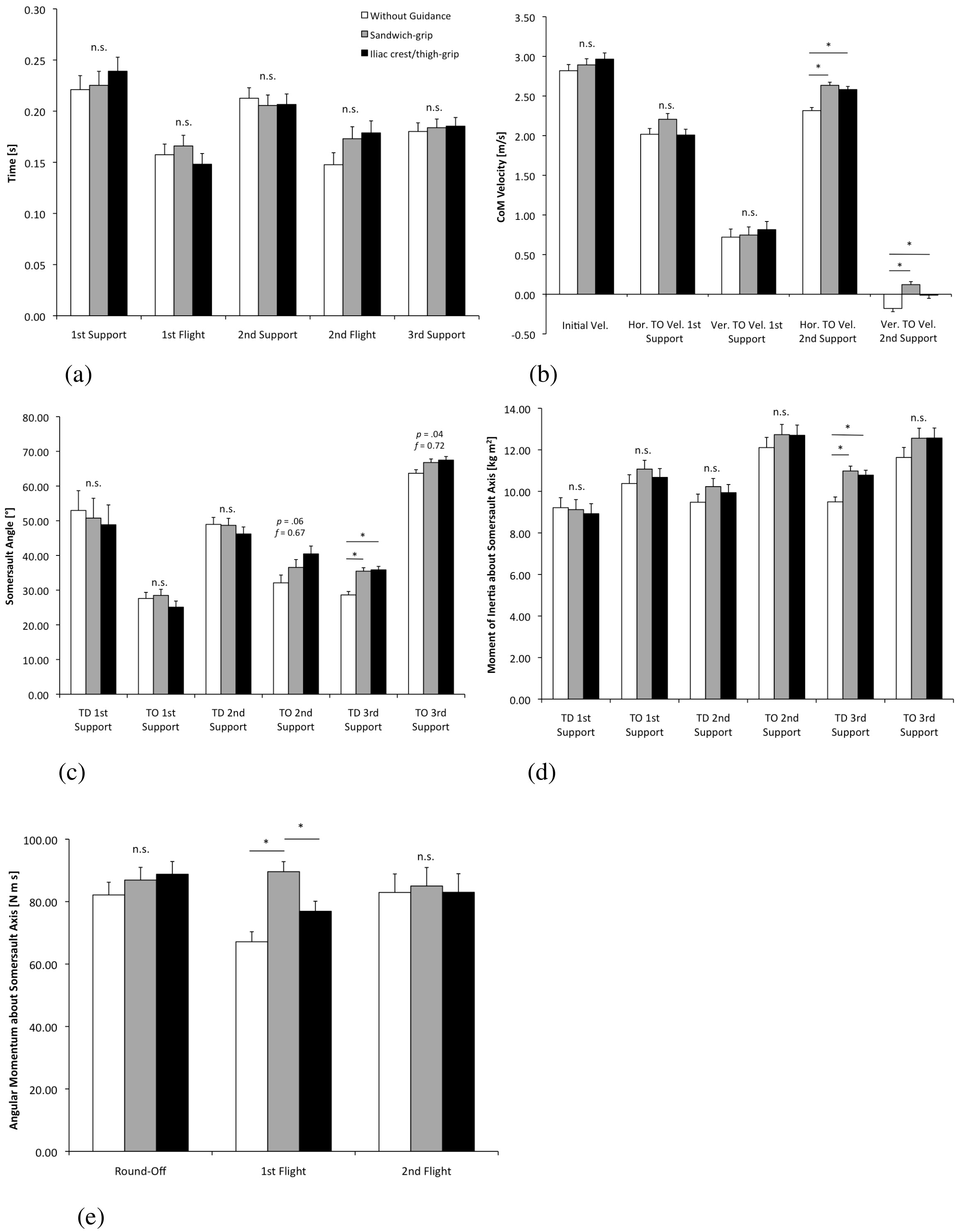
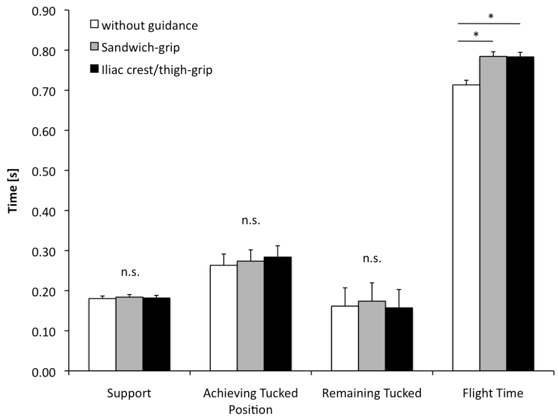
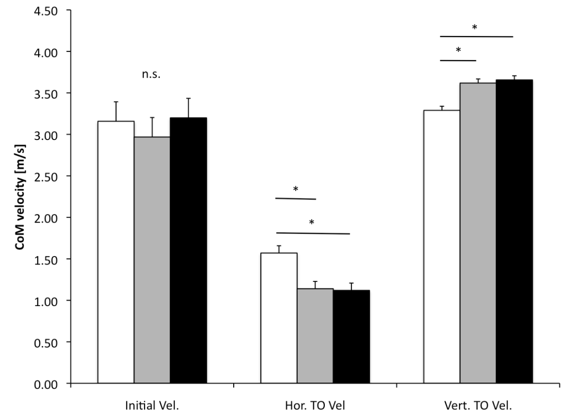


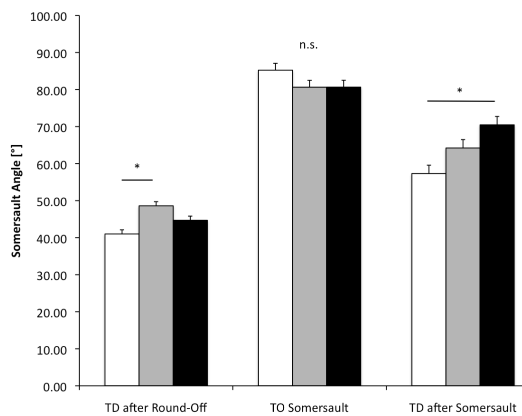
Figure 3. *Key kinematic parameters when performing the combination round-off back handspring in the no-guidance condition and the two guidance conditions: (a) variables related to the time-structure, (b) variables related to the center of mass's velocity, (c) somersault angle, (d) moment of inertia about transverse axis, and (e) angular momentum about the transverse axis. * denotes differences (p < .05) according to Tukey's HSD post-hoc test.*



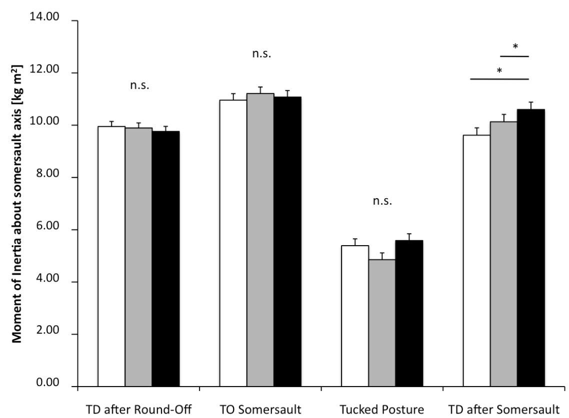
(a)



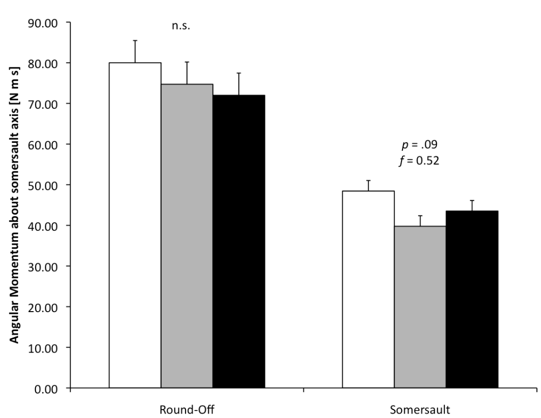
(b)



(c)



(d)



(e)

Figure 4. *Key kinematic parameters when performing the combination round-off somersault in the no-guidance condition and the two guidance conditions: (a) variables related to the time-structure, (b) parameters related to the center of mass's velocity, (c) somersault angle, (d) moment of inertia about transverse axis, and (e) angular momentum about the transverse axis. * denotes differences (p < .05) according to Tukey's HSD post-hoc test.*

DISCUSSION

The purpose of this case study was to identify the effects of two different manual guidance procedures on movement kinematics in two routines in gymnastics, namely the back handspring and the somersault after a preceding round-off. Based on assumptions of high-level coaches we hypothesized, that both guidance procedures should neither change the time-structure, the somersault angle, nor the moment of inertia about the somersault axis in the round-off back handspring. Furthermore, we assumed, that the iliac crest/thigh-grip should have a stronger effect on angular momentum and the sandwich-grip should have a stronger effect on the velocity of the center of mass. Regarding the round-off back somersault routine, we assumed, that both guidance procedures should neither influence the somersault angle, the moment of inertia nor the angular momentum about the somersault axis. We furthermore hypothesized, that both guidance procedures should have a significant effect on the time-structure and the velocity of the center of mass. We analyzed movement kinematics of female gymnasts in the two skills with and without guidance.

When performing the round-off back handspring, gymnasts exhibited a larger horizontal take-off velocity, a larger vertical take-off velocity, a larger somersault angle at touch-down to third support, and a larger moment of inertia at touch-down to third support when guided with either the sandwich-grip or the iliac crest/thigh-grip compared to the no-guidance condition. Gymnasts showed a larger angular momentum about the somersault axis when guided with the sandwich-grip but not when guided with the iliac crest/thigh-grip.

Since it is a main aim of the round-off back handspring to maintain or enhance the translational and the rotational component of the movement (cf., Knoll, 1999) it can be speculated, that the sandwich-grip helped the gymnast to achieve this goal partly by not “loosing” angular momentum from the round-off to the first flight phase, but rather maintaining it. The translational component of the routine was further optimized when using the sandwich-grip, because the vertical take-off velocity after the second support phase was positive, indicating an upward movement of the center of mass which may have been resulted from an optimization of the joint torques and the impulse during the support phase (Yeadon & King, 2002). This in turn may lead to an optimized third flight phase to prepare the following movement.

From the experience of one of the authors as a former national level coach, we argue that if the gymnasts would have been asked to perform a subsequent somersault, this somersault would have been performed technically better when the back handspring would have been guided with the sandwich-grip compared to the iliac crest/thigh-grip. However, the gymnasts in our study were asked to perform only a straight jump after the back handspring. Because there was no instruction to optimize the final jump, we cannot support the aforementioned argumentation from our data. We conclude that both guidance procedures fulfill similar demands in the round-off back handspring routine. However, if the coach’s interest is to optimize the angular momentum about the somersault axis and the second flight phase, then the sandwich-grip should be applied in the first instance.

When performing the round-off back somersault, gymnasts in our study exhibited longer flight times, as well as larger vertical take-off velocities, smaller horizontal take-off velocities, and a larger moment of inertia at touchdown after the somersault when guided with either the sandwich grip or the iliac crest/thigh-grip. Gymnasts showed higher values for the somersault angle at touchdown after round-off when guided with the sandwich grip and a larger somersault angle at touch-down after the somersault when guided with the iliac crest/thigh-grip as compared to the no-guidance condition.

The reduced horizontal take-off velocity together with the increased vertical take-off velocity after the support phase indicates an optimized impulse and therefore an optimized deflection of the center of mass's trajectory during the support phase in both guidance conditions. When applying the sandwich-grip, the gymnast was in a more upright position at touchdown after the round-off which could lead in an optimized load distribution in the passive structures of the musculoskeletal system (Brüggemann, 2000) and an optimization of the joint torques during the support phase (Yeadon & King, 2002). A longer flight time (which was found in both guidance conditions) could help gymnasts to optimize their landing preparation (Davlin et al., 2004). However, a longer flight time may also result in higher reaction forces during touchdown (Brüggemann, 2000; McNitt-Gray, 2000), and it can be assumed, that the load distribution was optimized during landing when using the iliac crest/thigh-grip because the gymnast landed in a more upright position. The coach's hand on the gymnast's belly prior to the landing phase could trigger tactile information on the abdominal muscles, leading to a task intrinsic feedback that may not be optimal for competitive gymnasts, because these gymnasts in general show only marginal activation of the abdominal muscles during the landing phase of a back tuck somersault (Brüggemann, 2000).

In the round-off back tuck somersault routine the optimal guidance procedure would be to initially use the sandwich-grip to help the gymnast optimizing the support phase. Before the gymnast reaches the tucked position the coach should switch to the iliac crest/thigh-grip to help the gymnast optimize his or her landing phase. The coach should prepare the landing area with a cushioning surface to act upon the to be expected higher reaction forces due to the longer flight time. If the sandwich-grip is used to guide the landing phase anyhow (which may be necessary when the gymnast makes specific movement errors), the coach should try to reduce the forces on the gymnast's belly to a minimum to provide an optimized task intrinsic feedback.

We want to highlight three specific aspects in our study that need to be taken into account in further experiments. First, manual guidance was provided on an optimal level for each gymnast, depending on her current mastery level of the task at hand, but the precise amount of force the coach applied during each trial was not controlled in our experiments. It would be of interest to assess the applied forces by using gloves with integrated pressure measurement sensors. This measurement could more specifically answer the question when exactly the forces were applied and how large they were.

Second, we analyzed movement kinematics of the two routines but did not assess muscular activation or ground reaction forces. Since there are wireless sensors available to measure muscular activation in complex movements and there are tumble tracks equipped with force plates it would be of interest to analyze the interplay between changes in muscular activation, changes in movement kinematics and changes in ground reaction forces in different guidance conditions. This could provide a more detailed analysis on the possible causes of the effects of different guidance procedures on complex skills in gymnastics.

Third, we only had one high level coach providing manual guidance but did not ask different coaches to provide manual guidance. Furthermore, we had 6 near expert gymnasts in our study but did not analyze novice gymnasts. Therefore the conclusions of our study may be limited to the effect of manual guidance on movement kinematics in the optimization of the two different routines. In order to generate more general conclusions about the effects of different manual guidance techniques, subsequent studies should incorporate a group of coaches in their design. It could furthermore be fruitful to recruit gymnasts on different levels of mastering the target skill in order to evaluate differential effects of manual guidance on movement kinematics.

CONCLUSIONS

We conclude, that the optimal guidance procedure in the back somersault would be to use the sandwich-grip to help the gymnast to optimize the support phase. During the landing phase, the iliac crest/thigh grip should be used in the first instance. We further conclude that both guidance procedures fulfill similar demands in the round-off back handspring routine, if the general aim is to optimize an already mastered routine. However, if the coach's interest is to particularly optimize the angular momentum about the somersault axis and the second flight phase, then the sandwich-grip should be applied in the first instance. We state that manual guidance seems to be a powerful technique for influencing the movement kinematics of complex motor skills in gymnastics if it is applied in a differential and professional manner, and its effects on movement kinematics seem to be strongly task dependent.

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