EFFICACY OF WRIST STRATEGY COACHING ON HANDSTAND PERFORMANCES IN NOVICES: INVERTING EXPLICIT AND IMPLICIT LEARNING OF SKILL-RELATED MOTOR TASKS

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Original article

Abstract

In gymnastics, mainstream handstand coaching emphasizes developing an aligned rigid body configuration, frequently leaving wrist-controlled balance work to implicit learning. However, skill-related motor behavioral research suggests the wrists to primarily contribute postural control in handstands. Considering recent research on handstands revealing experience-dependent motor behavior, the present study aimed to examine motor learning effects of explicit wrist usage coaching on handstand performances in skilled and less skilled novices. Therefore, twenty-five volunteering sport students served as participants completing a three-week training intervention which solely and explicitly addressed successful wrist usage during handstand. A video-tutorial introducing participants to the wrist strategy of hand balance preceded five practical training sessions that all neglected providing explicit postural advice. Participants performed three handstands on a plane gymnastics mat prior to (pre-test) and after (post-test) completing the training intervention. Standardized video recordings of each trial allowed retrospective group assignment (skilled and less skilled novices) based on pre-test mean balance times. With this, balance times, expert assessments (postural execution and balance control strategies) and goniometric analyses of shoulder and hip joint angles served to detect practical changes in handstand performances. Enhanced balance times as well as increased scores for postural execution and balance control strategies were revealed for less skilled novices ($p < .05$), but not for skilled novices ($p > .05$). Furthermore, in both groups changes in shoulder and hip joint angles failed significance. In conclusion, present findings suggest practitioners to make entirely unexperienced handstand learners explicitly aware of the wrist strategy's operating principle.

Keywords: *skill acquisition, balance, postural control, declarative knowledge, model observation.*

INTRODUCTION

"You make a hollow back" or "open your shoulder angle" are regular phrases gymnastics coaches use to comment on defective handstand performances. Augmented feedback and instructions have obtained widespread acceptance to benefit motor skill learning (Schmidt & Lee, 2011). However, are suchlike explicit advice sufficient? And what is considered as crucial for learning handstands at all? With the handstand on the floor being an essential postural motor task in gymnastics

(Hedbávný, Sklenaříková, Hupka, & Kalichová, 2013), contemporary educational concepts on motor learning in handstand acquisition are suggested to respond these questions from interdisciplinary perspectives.

In general, a biomechanical point of view promises valuable knowledge regarding essential qualities for successful handstand performances. Due to modern technology allowing mobile data collection during sport-specific movements (Vogt, Kato, Schneider, Türk, & Kanosue, 2017) and handstand performances in particular (Blenkinsop, Pain, & Hiley, 2016), decoding motor behavior in handstands has still received considerable attention in recent research (Blenkinsop, Pain, & Hiley, 2017; Kochanowicz et al., 2017; Kochanowicz et al., 2018). Based upon previous studies addressing upright and inverted stance dynamics (Kerwin & Trewartha, 2001; Yeadon & Trewartha, 2003), it is meanwhile well accepted that postural control mechanisms during handstand on a plane surface initially depend on contributing torques by the most inferior joint (i.e., wrist). Compared to other involved muscles, wrist flexor torques have recently been reported to show the highest mean EMG activity (i.e., 60% RMS normalized to an isometric MVC) in handstand balances (Kochanowicz et al., 2018). In case of increasing postural oscillations, synergistic shoulder and hip torques are additionally used to maintain balance control (Hedbávný et al., 2013). With this, Gautier, Marin, Leroy and Thouvarecq (2009) accentuated that angular hip joint adjustments are only used by low-level gymnasts, whereas handstand performances executed by high-level experts are characterized by corrective movements in the most inferior joints. However, regardless of the applied balance control strategy, movement patterns facilitating maintenance in handstand benefit from visual control (Asseman & Gahéry, 2005; Gautier, Thouvarecq, & Chollet, 2007) and remain the center of mass (CoM) vertically above the base of support (Kerwin & Trewartha, 2001). Thus, skill-related motor behavior in handstand can be modelled as a single-segment inverted pendulum (Blenkinsop et al., 2017) with the body balanced above the wrists as one steady object (Yeadon & Trewartha, 2003).

This in mind, high-level handstand performances and, thus, practice are suggested to approach two fundamental motor skills; (1) postural modulations leading to a linear rigid body configuration, (2) balance control abilities due to wrist flexor muscular activation. Considering that several biomechanical and motor behavioral studies only deal with handstand performances of experienced gymnasts (e.g., Gautier et al., 2009), current research on handstand skill acquisition in unexperienced learners indicates that the importance of these two respective aspects has rather been neglected in literature. Instead, several reports focused on the know-how of handstand coaching, referring to the expedient application of general knowledge about augmented feedback (e.g., Post, Aiken, Laughlin, & Fairbrother, 2016; Veit, Jeraj, & Lobinger, 2016) and observational learning (e.g., Andrieux & Proteau, 2016; Blandin, Lhuisset, & Proteau, 1999; Braun, 2016; Breslin, Hodges, & Williams, 2009; Buchanan & Dean, 2014; Hayes, Hodges, Scott, Horn, & Williams, 2006; Janelle, Champenoy, Coombes, & Mousseau, 2003; Laguna, 2008; Rohbanfard & Proteau, 2011). Regarding handstand acquisition, there are some studies investigating verbal (Masser, 1993), tactile (Croix, Lejeune, Anderson, & Thouvarecq, 2010) and several combined feedback (e.g., tactile-verbal and visual-comparative feedback; Rohleder & Vogt, 2018b) and observational learning strategies (Maleki, Nia, Zarghami, & Neisi, 2010). For example, Croix et al. (2010) suggest light finger contact on the thigh to increase gymnasts' balance abilities in handstands. Previously, Masser (1993) observed enhanced handstand performances in students evoked by the verbal instruction "shoulder over your knuckles". With these studies providing substantial insights into enhanced handstand education, research dealing with the weighting of crucial training contents (i.e. wrist work, postural adaptations) with respect to explicit (EL) and implicit learning (IL; Sun, Merrill, & Peterson, 2001) is still lacking. Aiming for efficient coaching, it is well accepted that the complexity of potential effects regarding EL and IL has to be taken into account, particularly with respect to adversely affected performances due to reinvestment (Lam, Maxwell, & Masters, 2009; Malhotra, Poolton, Wilson, & Omuro, 2015; Masters & Maxwell, 2008; Verburgh, Scherder, van Lange, & Oosterlaan, 2016). While reports by Uzunov (2008) as well as Rohleder and Vogt (2018) suggest that wrist work and a proper body line seem to be mutually dependent for successful handstands, current training methodology privileges the explicit development of the postural alignment preceding wrist-related practice (Uzunov, 2008). Considering recent reports suggesting the wrist strategy to be the most dominant control strategy even in perturbed handstand balances (e.g., Blenkinsop et al., 2017), the relatively low status of explicit hand balance abilities in current handstand educational concepts may be challenged. Conscious of facilitated balance practicing due to preceding learning of postural stabilization, however, investigations on adapted EL-based handstand coaching providing declarative knowledge regarding wrist usage, accompanied by only implicit postural training, remain to be elucidated in consideration of different skill levels (Gautier et al., 2009; Kochanowicz et al., 2018; Vogt et al., 2017).

Approaching altered learning of skill-related motor tasks compared to predominant handstand training, this study aimed to examine motor learning effects of explicit wrist strategy coaching on handstand performances in skilled and less skilled novices. With respect to presumably existing non-declarative knowledge regarding the wrist strategy in skilled novices, it is hypothesized that (1) less skilled compared to skilled novices show training-induced increases in balance time that are related to enhanced postural control patterns. (2) Less skilled compared to skilled novices are further hypothesized to show training-induced enhancements in postural performances that reflect beneficial effects of IL regarding an aligned body configuration.

METHODS

Thirty-two volunteering sport students (17 females: M_{age} = 20.71, *SD* = 0.99 years; M_{height} = 167.85, *SD* = 7.38 cm; M_{weight} = 59.68, *SD* = 7.17 kg; 15 males: M_{age} = 22.07, *SD* = 1.67 years; M_{height} = 183.40, *SD* = 5.77 cm; M_{weight} = 77.93, *SD* = 7.27 kg) were recruited from university courses to participate in this study. Volunteers who gained gymnastics experience well beyond school classes (i.e., particular history in organized gymnastics training systems) were excluded a priori. However, passing the university's physical aptitude test guaranteed participants' fundamental skill-related experience regarding the lunge entry and swing up to handstand movement. The study received approval by the University's Human Research Ethics committee in compliance with the Declaration of Helsinki. All participants provided written consent.

Unaware of the experimental hypotheses, participants completed two experimental protocols (pre- and post-test) each comprising three trials (Gautier et al., 2007) of swinging up to handstand on the floor. Withholding augmented advice addressing a resistant linear body configuration, each participant was instructed beforehand to aim for long maintenance in handstand with their feet kept close together. Following individual warm up and preparation (handstands were not permitted), one single handstand rehearsal served as familiarization preceding test trials (Rohleder & Vogt, 2018a). In absence of any rules describing a standardized termination of the handstand position, participants were allowed to roll over, to leave the handstand sideways or to place their feet back. Any changes of the hand position during handstand led to discontinuation of the trial. Approaching sport-specific conditions in consideration of a user-orientated environment (Rohleder & Vogt, 2018b), the experiment was conducted in the University's gym using a certified gymnastics mat to perform the handstand trials. A rectangular corridor (dimensions: 80 × 30 cm) was affixed on the mat using white tape to standardize the position of hand support during handstand (Figure 1C).

Pre-tests were performed as described within one week (i.e., week 1; Figure 1A). Subsequently, participants received a video-tutorial providing concise declarative knowledge concerning the operating principle of the wrist strategy for successful handstand balances (Blenkinsop et al., 2017; Kerwin & Trewartha, 2001; Yeadon & Trewartha, 2003). Taking the current stage of research concerning effective observational learning into account, the tutorial used a mixed-model approach (Rohbanfard & Proteau, 2011) presenting one failed and one successful wrist-controlled hand balance. Video sequences were accompanied by screenshots and verbal comments (Janelle et al., 2003) raising participants' awareness for wrist-related knowledge of performance (Laguna, 2008) and models' skill level (Andrieux & Proteau, 2016). Limiting attentional cueing to wrist-related features ensured explicit and consistent focusing on the wrists' skill-related relevance (Breslin et al., 2009; Buchanan & Dean, 2014). Hence, advice stressing critical cues to facilitate postural adjustments were not taught.

Combining observational learning with physical practice (Blandin et al., 1999), participants completed five training sessions within the following three weeks (Maleki et al., 2010; Masser, 1993) including two sets of six different exercises. Based on afore conveyed expertise, all exercises intended skill-related motor control in terms of wrist flexor activation during handstand on a plane surface. Partially inspired by Uzunov (2008), exercises (E1-E6) were designed as follows (Figure 1B):

- E1: Winding up a rope (due to wrist flexions) which is connected with a weight plate (1.25 kg).
- E2: Oblique standing with straight arms parallel next to the ears and repeated hand pushing against a wall leading to sole wall touch by the fingertips.
- E3: Knee rest and repeated palmar flexion of the wrists (forehand view) with a weight plate (1.25 kg) in each hand.
- E4: Free practicing of the lunge entry and swing up to handstand aiming for a vertically placed CoM above the fingers. Self-controlled video feedback (delay: 12 sec) was provided using a tablet PC (iPad Air) (Post et al., 2016).
- E5: Free standing with straight arms parallel next to the ears and performing repeated palmar flexions of the wrists with a weight plate (1.25 kg) in each hand.
- E6: Lunge entry and swing up to handstand leaning the thighs against a bar (fingertips approximately 10 cm away from the bar's perpendicular) and removal of the thighs from bar contact (Croix et al., 2010) due to sole wrist flexions. Pushing the bar actively by the legs was explicitly prohibited.

In accordance with the video-tutorial, exercises aimed for explicit wrist flexor activation triggered by locating the CoM vertically above the support surface (i.e., E4 and E6). In favor of visual control (Asseman & Gahéry, 2005), participants were encouraged to gaze their hands throughout all exercises. Referring to recommended training loads (Uzunov, 2008), each exercise was executed for approximately thirty seconds followed by a self-determined recovery period (≤ 30 s). Postural adaptations and a controlled dosing (i.e., self-paced velocity) of the swing up to handstand movement were only addressed implicitly without any explicit cueing provided by the experimenters. After completion of the third training week, the post-test was conducted during the following week in conformity with the pre-test's modalities (Figure 1A).

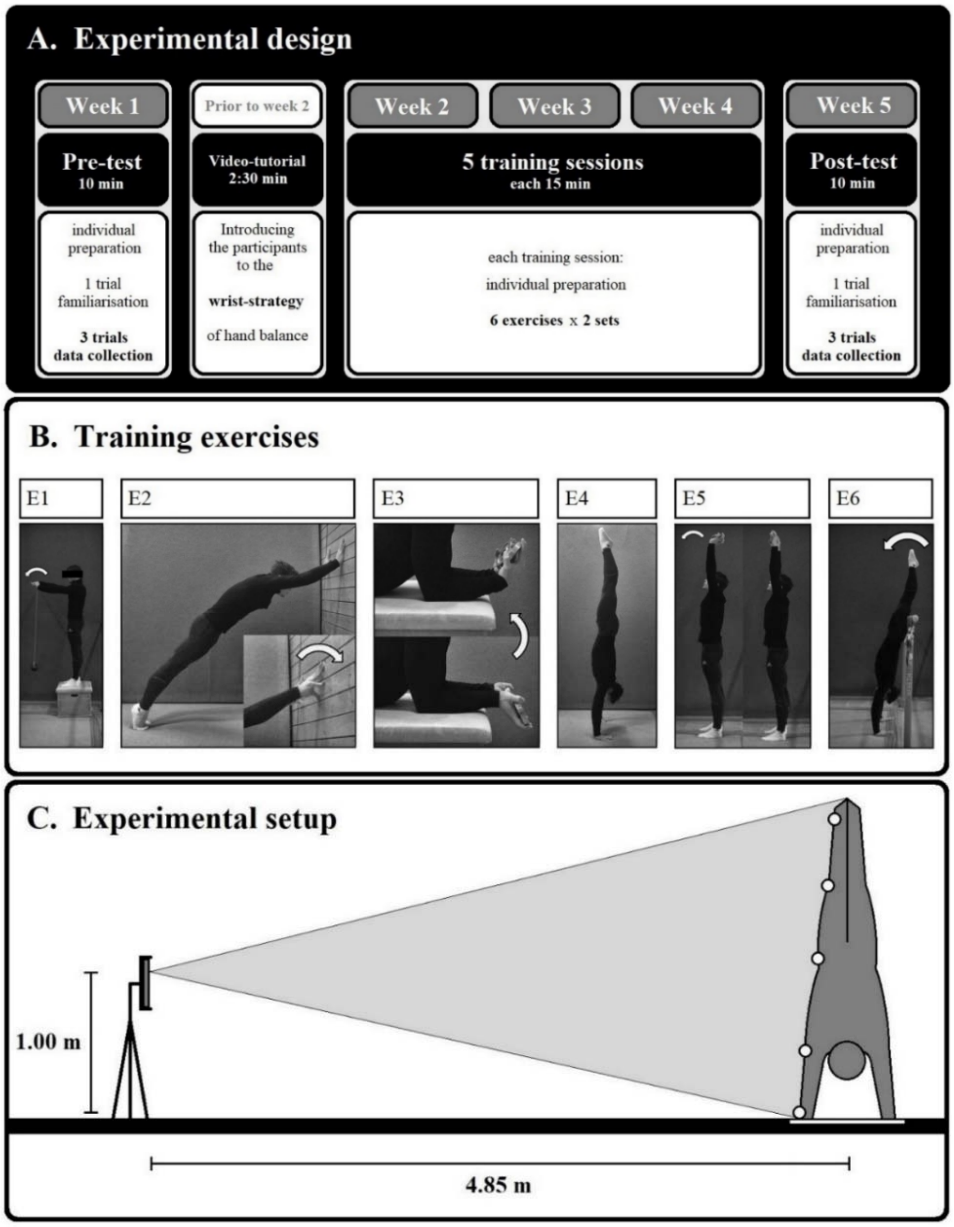

Figure 1. Schematic view displaying (A) the experimental design of the overall procedures, (B) the exercises performed within the training interventions (here: accurate execution quality by an experienced gymnast to emphasize the basic intention of the exercises best possible) and (C) the experimental setup for data collection.

Following a practical approach, a tablet PC (Apple iPad Air, frequency: 60 Hz; resolution: 1080p) was used to record all trials capturing the movement task in the sagittal plane. The tablet PC was fixed to a tripod at a height of one meter (distance to the middle of support surface: 4.85 m) ensuring a standardized point of view (Rohleder & Vogt, 2018a; Figure 1C). Tape markers were attached to the following anatomical landmarks to track the position of crucial body segments; 1: wrist (ulnar-styloid process), 2: shoulder (posterior deltoid), 3: hip (femur greater trochanter), 4: knee (lateral epicondyle of femur), 5: ankle (fibula apex of lateral malleolus). Based on recorded video sequences, kinematic data were further determined using the Kinovea 0.8.15 software.

In line with official criteria of the International Gymnastics Federation (FIG) concerning point deductions for handstand performances due to angular deviations (FIG, 2017), the balance time in handstand was measured using a corridor limited by a deviation of 15° to each side of vertical line above the wrists (Rohleder & Vogt, 2018a). With this, time measuring was started when both legs (ankles and knees) initially entered the corridor following the swing up to handstand. Moreover, time measuring was discontinued under the following conditions; 1: corridor exit of the feet or knees, 2: Initiation of the rolling over movement (i.e., incipient arm bending or rolling in of the head), 3: Initiation of the back placing of the feet (i.e., incipient increase of the maximum reduced feet gap).

The quality of postural execution was evaluated by four independent artistic gymnastics experts (i.e., two nationally licenced coaches and two judges; two male and female each) assigning scores between 0.0 and 10.0 points to each trial matching current FIG rules (FIG, 2017). For this, experts were briefed to completely neglect participants' balance time in handstand. Instead, experts were instructed to particularly evaluate unsteadiness, slightly bent arms and legs (in accordance with the criteria described in 2.4.1) as well as angular deviations from the perfect hold position (FIG, 2017). Trials of each participant (i.e., 3x pre-test; 3x post-test) were presented to the experts in randomized order.

Additionally, experts were asked to assign one of five balance control strategies to each trial with respect to the externally visible postural correction mechanisms in anterior-posterior direction. Balance control strategies were characterized as follows (Figure 2):

- Wrist strategy (4 points): robust body configuration from wrists to ankles with apparent wrist-controlled balance corrections
- Shoulder strategy (3 points): robust body configuration from shoulders to ankles with apparent shoulder-controlled balance corrections
- Shoulder-hip-coupling (2 points): apparent contrary shoulder- and hip-controlled balance corrections
- Hip strategy (1 point) robust body configuration from wrists to the hip with apparent hip-controlled balance corrections
- "No strategy" (0 points): no apparent motor skills to maintain the handstand position

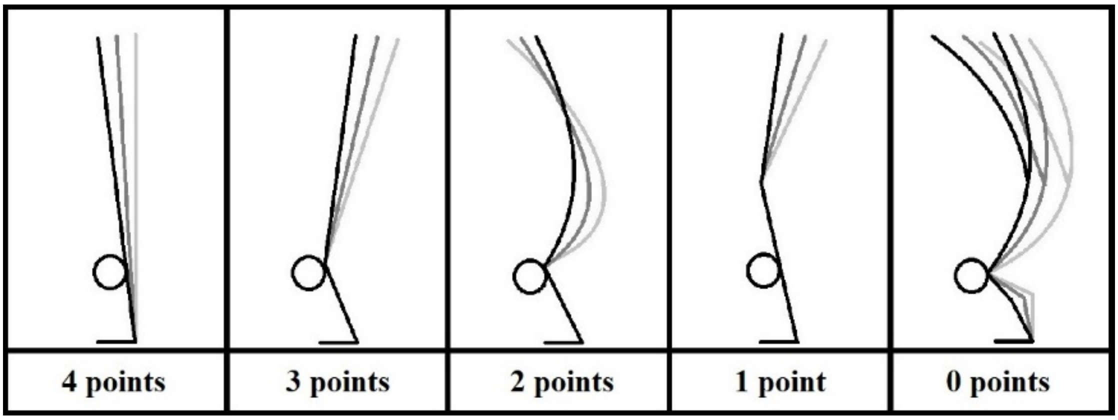

Figure 2. Categories of anterior-posterior balance control strategies in handstand assigned by the experts (inspired by Blenkinsop et al., 2017 and Gautier et al., 2009). Classification: The larger the distance of the primarily correcting joint to the support surface, the lower the points for the applied balance control strategy

Goniometric analyses focused on large body joints (i.e., shoulder and hip joint) which, except for the wrists, have been suggested to primarily contribute to postural control during handstand performances (Gautier et al., 2009). To determine joint-related angular changes during handstand, the individual optimum of each handstand trial was identified (Masser, 1993) based on predefined criteria derived from Rohleder & Vogt (2018b); (1) in case of rolling over trials, the moment where the participants' feet reached their highest point was set as optimum, (2) in case of trials characterized by side or back placement of the feet, the moment of incipient leg straddling or spreading served as optimum.

Due to conflicting schedules or unpredicted injuries caused by their sport studies, six participants did not complete the full experimental procedure and were excluded from statistical analyses. After checking interval scaled variables (balance time, shoulder angle, hip angle) for outliers using the 2σ-method, remaining participants (n = 25) were assigned to two groups based on rankings of attained pre-test mean balance times. Inspired by Vogt et al. (2017), the ranking list was divided into a long-balancing half ($M_{\text{balance time}}$ = 1.13 s, *SD* = .42, n = 13) and a short-balancing half ($M_{\text{balance time}}$ = .41 s, *SD* = .18, n = 12). According to this bisection of rankings (unpaired *t*-test revealed $t[23] = 5.40$, $p < .01$), participants were classified as skilled (long-balancing half) and less skilled novices (short-balancing half) for further analyses.

Repeated measures analyses of variance (ANOVAs) were computed for each dependent interval scaled variable (i.e., balance time, shoulder and hip angle) including group (skilled vs. less skilled) as between factor and test (pre- vs. post-test) as within factor. Further, pairwise comparisons (i.e., paired and unpaired *t*-tests) were calculated post hoc. For ordinal scaled variables (i.e., postural execution, balance control strategy), Wilcoxon signed-ranks tests and Mann-Whitney-U-tests were immediately performed as pairwise comparisons. All calculations for pairwise comparisons were adjusted for multiple testing by applying Bonferroni-Holm corrections. Kendall's coefficient of concordance (*W*) was calculated to ensure interrater reliability of the ordinal scaled variables concerning expert judgements (postural execution: $W(149) = .787$, $p < .01$; Balance control strategy: $W(149) = .487$, $p < .01$). Partial eta-squared (η^2_p) was used to identify ANOVAs' effects, whereas Cohen's *d* effect sizes were calculated to interpret pre-to-post changes. Statistical analyses were performed using the SPSS 25.0 software (International Business Machines Corp., Armonk, NY, USA). The level of significance was set at $p < .05$. Data in the text, tables and figures are presented as means (M) ± standard deviations (SD).

RESULTS

Balance time

Repeated measures ANOVA revealed significant interactions between factors group and test, $F(1, 23) = 6.40$, $p < .05$, $\eta^2_p = .22$; however, main effects revealed no differences for tests, $F(1, 23) = 1.88$, $p > .05$, $\eta^2_p = .08$. Post hoc tests showed significant enhanced balance times for less skilled, $t(11) = 3.93$, $p < .01$, $d = 1.30$, but not for skilled novices, $t(12) = .69$, $p > .05$, $d = .27$; further, post hoc tests showed significant group differences in the pre-test, $t(23) = 5.40$, $p < .01$, which were not obtained for the post-test, $t(23) = .92$, $p > .05$ (Figure 3; Table 1).

Postural execution

Wilcoxon signed-ranks test showed significantly increased scores for postural execution in less skilled novices, $Z = -2.67$, $p < .05$, $d = .79$, but not for skilled novices, $Z = -1.71$, $p > .05$, $d = .47$; further, Mann-Whitney-U-test showed significant group differences in the pre-test, $U = 22.50$, $p < .01$, which were not obtained for the post-test, $U = 77.50$, $p > .05$ (Figure 3; Table 1).

Balance control strategy

Wilcoxon signed-ranks test showed significantly increased scores for balance control strategy in less skilled novices, $Z = -2.43$, $p < .05$, $d = .91$, but not for skilled novices, $Z = -1.15$, $p > .05$, $d = .43$; further, Mann-Whitney-U-test showed no significant group differences in the pre-test, $U = 45.50$, $p > .05$, and in the post-test, $U = 63.00$, $p > .05$ (Figure 3; Table 1).

Goniometric analysis

Shoulder angle: repeated measures ANOVA revealed no interactions between factors group and test, $F(1, 23) = 1.43$, $p > .05$, $\eta 2p = .06$; further, main effects revealed no differences for tests, $F(1, 23) = 1.86$, $p > .05$, $\eta 2p = .08$ (Figure 3; Table 1).

Hip angle*: r*epeated measures ANOVA revealed no significant interactions between factors group and test, $F(1, 23) = 5.09$, $p > .05$, $\eta^2_p = .18$; further, main effects revealed no differences for tests, $F(1, 23) = .01$, $p > .05$, $\eta^2_p = .00$. (Figure 3; Table 1).

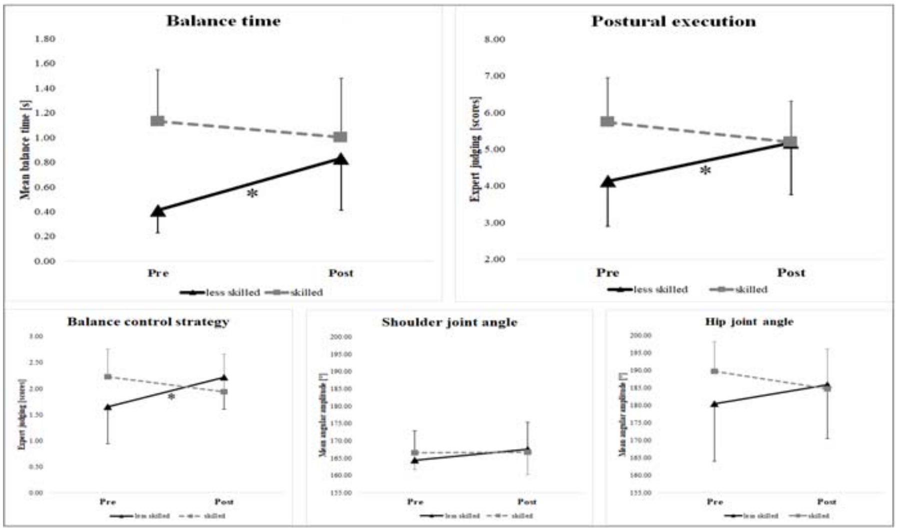

Figure 3. Interaction plots displaying means ± standard deviations for group-related changes (less skilled vs. skilled novices) of factors balance time, postural execution, postural control strategy as well as shoulder and hip joint angle. Level of significance in pairwise comparisons (adjusted to Bonferroni-Holm-corrections): *$p < .05$.

Table 1
Changes in handstand performances (means ± standard deviations) during pre- and post-test for less skilled and skilled novices.

	Less skilled		Skilled	
	Pre-test	Post-test	Pre-test	Post-test
Balance time [s]	0.41 ± 0.18	0.83 ± 0.42	1.13 ± 0.42	1.00 ± 0.48
Postural execution [points]	4.13 ± 1.23	5.18 ± 1.42	5.74 ± 1.21	5.19 ± 1.12
Balance control strategy [points]	1.65 ± 0.53	2.22 ± 0.72	2.23 ± 0.71	1.94 ± 0.61
Shoulder angle [°]	164.47 ± 8.40	167.58 ± 7.83	166.59 ± 4.95	166.79 ± 6.59
Hip angle [°]	180.45 ± 16.45	185.86 ± 15.39	189.69 ± 8.48	184.74 ± 11.44

DISCUSSION

The present study aimed to examine motor learning effects of explicit wrist strategy coaching on handstand performances in skilled and less skilled novices. With pre-test mean balance time rankings serving as criterion for skill level-based group assignment (i.e., skilled vs. less skilled novices), enhanced mean balance times, scores for postural execution and postural control strategies were observed in less skilled compared to unaffected parameters in skilled novices. Furthermore, in both groups changes in shoulder and hip joint angles failed significance.

According to our initial first hypothesis (1), increased mean balance times in less skilled novices reflect beneficial effects of EL evoking declarative knowledge (Sun et al., 2001) in entirely unexperienced learners regarding the wrist strategies' operating principle (Blenkinsop et al., 2017; Kerwin & Trewartha, 2001; Yeadon & Trewartha, 2003). With this, increased handstand balance times in less-skilled novices support combined physical practice with observational learning and augmented feedback to accelerate general (Magill, 2014; Schmidt & Lee, 2011), gymnastics-related (Braun, 2016; Veit et al., 2016) and even handstand-specific skill development (Maleki et al., 2010). However, while all participants (i.e., skilled and less skilled) received the same literature-based video-tutorial (e.g., Andrieux & Proteau, 2016; Janelle et al., 2003; Rohbanfard & Proteau, 2011) and training intervention (e.g., Asseman & Gahéry, 2005; Post et al., 2016; Uzunov, 2008), unaffected mean balance times in skilled compared to less skilled novices have to be discussed in light of large standard deviations and EL-induced performance-influencing factors (Lam et al., 2009; Malhotra et al., 2015). Taking recommended and, thus, implemented consistency in attentional directing and movement task usage into consideration (Breslin et al., 2009; Buchanan & Dean, 2014), there are reasons to assume that the present study's findings may be attributed to the reinvestment theory by Masters and Maxwell (2008) suggesting declarative task-relevant knowledge (i.e., wrist strategy usage) to interfere already automated motor processes which were presumably present in the skilled group prior to the intervention. Facing this, it seems reasonable that task-relevant knowledge may occasionally impair more skilled handstand balances (Masters & Maxwell, 2008), apparently independent of the approached coaching focus regarding skill-related motor tasks (e.g., wrist strategy usage vs. postural stabilization; Rohleder & Vogt, 2018a). Nevertheless, although showing negative tendencies, it has to be taken into account that impaired balance times and balance control strategies in skilled novices failed significance. Thus, interpretations of present effects with respect to reinvestment can only serve as assumptions and need further research. Furthermore, with Kochanowicz et al. (2018) and Gautier et al. (2009) reporting skill level dependencies of balance control, groups are considered to reflect emerging differences regarding altered motor behavior as a result of the training intervention. However, with respect to this, present findings disclose inconsistencies in view of comparable studies. For example, facilitated handstand balances due to light thigh touch during testing were revealed for experienced gymnasts (Croix et al., 2010). On the one hand, this contradicts advantageous balance performances in less skilled compared to skilled participants in the present study following training including a tactile advice on the thigh (E6). On the other hand, in the present study contact on the thigh was only applied during training, but not during testing which interferes comparability. Furthermore, Croix et al. (2010) then again applied a lateral touch compared to a dorsal touch in the present study and related enhanced balancing to the lateral, but not to the anterior-posterior direction which is essentially approached in the present study. With this, skill level-related comparisons must take the level of experience and setup-alterations into account in more detail. Using laboratory setups, Kochanowicz et al. (2018) compared two experienced groups (young and adult gymnasts) as well as Gautier et al. (2009) comparing high-level and low-level experts who were all able to maintain in the handstand for at least twenty seconds. Thus, although filling a stated research gap according to efficient coaching on wrist usage in handstand acquisition (Rohleder & Vogt, 2018a), broad evidence regarding motor behavior in experienced gymnasts (Blenkinsop et al., 2017; Gautier et al., 2007; Gautier et al., 2009; Kochanowicz et al., 2017; Kochanowicz et al., 2018) remains indistinct for unexperienced performers and, thus, complicates integrating our findings into an appropriate context of literature. This encourages to further elucidate novices motor behavior in response to altered educational concepts approaching EL and IL effects in handstand acquisition.

According to our second hypothesis (2), increased postural execution in less skilled novices suggests explicit wrist strategy coaching to even induce posture-related IL leading to more aligned body configurations. These findings confirm well-accepted knowledge regarding IL benefits (Lam et al., 2009; Verburgh et al., 2016) and are additionally in line with comparable studies reporting enhanced postural performances in handstands following feedback- and observation-based interventions (Maleki et al., 2010; Masser, 1993; Rohleder & Vogt, 2018b). However, while the present study revealed enhanced postural configurations following IL, Maleki et al. (2010) related observational learning benefits to additional (explicit) verbal teaching. In addition, the verbal cue „shoulder over your knuckles" used by Masser (1993) provides declarative knowledge in terms of postural adaptations which is in contrary to the present study's approach revealing implicit body alignment in less skilled novices. Moreover, Maleki et al. (2010) assumed the skill level to influence observational and physical practice benefits, which was partially reflected by unaffected postural execution in skilled novices. Additionally, from a goniometric perspective, shoulder joint angles remained unaffected in both groups which is in conflict to a previous study by Rohleder and Vogt (2018b) reporting feedback-induced shoulder angle changes in handstand positions in the absence of hip-related effects. Challenging these contradictory reports, it seems reasonable that the studies' divergent primary objectives which were explicitly taught to the participants a priori may have caused different postural adaptations. While Rohleder and Vogt (2018b) explicitly addressed high postural execution quality neglecting maintenance in handstands, the participants in the present study were exclusively instructed to aim for a long balance time, which may eventually induce different movement patterns regarding postural control. Additionally, although failing significance, slightly increased hip angles in less skilled novices provide reasons to assume that unexperienced learners implicitly tend to use opening the hip joint in order to locate the CoM vertically above the support surface. Although the comparability of skill-levels is partially limited, this assumption is in line with Gautier et al. (2009) reporting low-level experts to prefer increased hip joint involvement to coordinate postural control. Necessitating further research, this might indicate implicit postural adaptations in response to EL regarding wrist usage.

In summary, the present study's findings legitimize the underlying approach of handstand coaching concepts strictly geared to skill-related motor behavior in terms of an increased explicit focus on wrist usage. Confirming initial assumptions from previous reports (Rohleder & Vogt, 2018a), explicit wrist strategy coaching neglecting any kind of posture-related advice benefits comprehensive handstand acquisition in less skilled novices including enhanced balance and, remarkably, enhanced quality in handstands' postural execution. This is, at least in parts, in contrary to Uzunov (2008) suggesting rigid body line development preceding balance training. However, efficacy of wrist-related handstand coaching seems to be ineffective to relatively skilled performers. While these negative effects may again be discussed with respect to EL effects on reinvestment (Masters & Maxwell, 2008), there is a further need to clarify if the practical training or the taught "know how" in the video-tutorial (or, presumably, the combination of both) essentially caused observed changes in handstand performances. Although studies prefer combined observational learning and physical practice (Blandin et al., 1999; Hayes et al., 2006), there are few studies indicating positive EL effects even without practical training (Maleki et al., 2010; Rohleder & Vogt, 2018b). This, for example, suggests further research to exclusively address observational learning introducing novices to the wrist strategy of handstand balances.

LIMITATIONS

Considering that the small number of participants generally limits the power of the present study, the recruited sample size seemed to be appropriate in relation to comparable studies in this research field (e.g., Croix et al., 2010). Nevertheless, we are well aware that a missing group of participants receiving no kind of coaching and practice represents a methodological limitation. Although further investigations are suggested to take an additional control group into consideration, the premeditated group assignment was deemed appropriate with respect to our comparative approach on motor learning effects in dependence on novices' skill level. Furthermore, although the unsteadiness of durations in handstand position (leading to high standard deviations) limits the present approach, we see this limitation as a necessary expense for a study aiming to serve as a kick off for applied research on the coaching of unexperienced handstand learners. Additionally, choosing a practice-orientated setup may be discussed in relation to reliable data collection. However, in view of comparable laboratory-based studies with similar shortcomings (e.g., Gautier et al., 2007; comparable low-frequency video sampling), reserves in data reliability are disproportionate to validity-related benefits of the chosen setup providing familiar and safe conditions to allow natural movement execution which is uninfluenced by impeding laboratory framework. Finally, it has to be taken into account that the differentiation between judging postural execution and balance control strategies was a necessary, but difficult task for judges which probably further limits the present study.

CONCLUSIONS

To conclude, the present study investigated effects of explicit wrist strategy coaching on novices' handstand performances depending on the skill level. Present findings (i.e., increased balance time and execution quality) suggest practitioners to make entirely unexperienced learners explicitly aware of the wrist strategy's operating principle. This is with respect to a no less important coaching of postural stabilization. With this study extending practice-oriented knowledge of efficient motor learning in handstand acquisition, appropriate educational strategies need further investigations approaching insights into skill-related motor behaviour, especially in unexperienced handstand learners.

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to all participants for their enthusiastic responses and reliable efforts in favor of the present study. This study was supported by an international grant of the German Academic Exchange Service (DAAD project no. 57320531) awarded to the supervising author.

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