TEACHING NOVICES THE HANDSTAND: A PRACTICAL APPROACH OF DIFFERENT SPORT-SPECIFIC FEEDBACK CONCEPTS ON MOVEMENT LEARNING

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Abstract

Due to rare evidence-based implications for the application of augmented feedback in gymnastics teaching, this study investigated whether standardised tactile-verbal feedback vs. visual-comparative feedback short-term enhance novel gymnasts' handstand postural performance and motor imagery. Twenty-six students (7 females, 19 males) were randomly assigned to the tactile-verbal feedback (age: 22.7 ± 3.9 years) or visual-comparative feedback (age: 21.9 ± 1.8 years) group (each $n = 13$), performing a pre-post designed experimental session of handstand trials. Conducting goniometric analyses for hip, shoulder and head position, feedback effects were monitored using video capture and a motion-doll. Shoulder positioning enhanced after receiving tactile-verbal feedback ($p < .01$), whereas shoulder angle imagery enhanced following visual-comparative feedback ($p < .05$). Furthermore, significant correlations between postural performance and motor imagery were found for head position after receiving tactile-verbal feedback ($p < .01$), whereas hip angle postural performance and motor imagery correlated significantly following visual-comparative feedback ($p < .01$). Tactile-verbal feedback and visual-comparative feedback effect several issues of motor learning in different manners; however, this is true even in a short-term approach. Thus, practical recommendations are suggested to consider combined feedback concepts to allow comprehensive handstand acquisition.

Keywords: *gymnastics, postural stability, balance program;motor imagery, skill assessment.*

INTRODUCTION

Regardless of the performance level, the handstand is one of the most essential gymnastics skills (e.g., Hedbávný, Sklenaříková, Hupka, & Kalichová, 2013). Learning to perform a high-quality handstand which is defined by absent angular deviations from the longitudinal axis (Hedbávný et al., 2013) yet requires sport-specific teaching expertise as well as adequate practicing periods. In this context, augmented feedback plays an important role in motor learning processes and is well accepted as a fundamental practical teaching technique (Magill & Anderson, 2012). However, comprehensive school and university curricula and schedules often do not permit spending cumulative time practicing for examination in addition to regular teaching times in class. With this, effective teaching designs are necessary to support short-term enhancements in motor skill acquisition. Further, (short-term) feedback concepts to enhance the handstand performance imply interdisciplinary challenges, including, for example, biomechanical and psychological parameters that have been reported to influence motor behaviour and even motor learning processes in gymnastics (Kerwin & Trewartha, 2001; Simonsmeier & Frank, 2016).

There are varied criteria by which motor learning in gymnastics can be determined. To assess progresses in practical handstand acquisition, as is the case in gymnastics lessons, the aesthetic quality of the handstand posture can be taken into account. In general, body position with a straight back and legs specifies the handstand posture enduringly (Johnson & Garcia, 1976). It is well-known that keeping a straight body shape without any angles in shoulder, elbow, hip, and knee joints are fundamentally required for high-quality handstand postures (Hedbávný et al., 2013; Uzonov, 2008). Therefore, the body‘s centre of mass has to be fixed above the hands and the head requires axial alignment to the spine without any gaps between shoulders and ears (Gerling, 2009; Uzonov, 2008). Todays' research on handstand has mainly focussed on the process of maintaining postural control (e.g., Hedbávný et al., 2013; Kerwin & Trewartha, 2001). Previous biomechanical research analysed the contributions made by joint torques in maintaining a handstand (Kerwin & Trewartha, 2001). There is evidence that wrist and shoulder torques are known to be essential for well-balanced handstand performances (Kerwin & Trewartha, 2001; Mohammadi & Yazici, 2016; Yeadon & Trewartha, 2003), whereas less successful balances are characterized by increasing hip torques (Gautier, Marin, Leroy, & Thouravecq, 2009; Kerwin & Trewartha, 2001). However, the hip strategy is a caused reaction to recover perturbed balances in upright stance (Runge, Shupert, Horak, & Zajac, 1999). Similar to normal upright stance, for the handstand equivalent joint involvement strategies of postural control are suggested (e.g., Gautier, Thouvarecq, & Chollet, 2007). In spite of intensive research on handstand balancing processes, studies dealing with the practical teaching of the reported expertise to learners are still lacking.

Within an effective-teaching approach on skill acquisition, from a psychological point of view conscious self-control of a performed movement always implies internal imagery, which is defined in the context of sport "as the creation and re-creation of an experience generated from memorial information" (Morris, Spittle, & Watt, 2005, p. 19) intending to, for example, generate motor programming and motor representation in the absence of actual movement (Schmidt & Lee, 2011; Jeannerod, 1994). Due to the fact that motor behavioural processes may depend on the structure of the internal motor representation (Noth, 2012; Schack, 2003), several studies have confirmed the quality of motor representation being essential for successful motor learning in technically demanding sports (Noth, 2012). For example, Schack and Mechsner (2006) have emphasised the hierarchical order of representational structures of the tennis serve in high-level compared to low-level tennis players resulting in increased long-term memory of movement patterns in expert players. It is well-accepted that cognitive abilities positively affect the process of motor skill learning (Simonsmeier & Frank, 2016) and imagery abilities are suggested to facilitate physical practice in gymnastics (d'Arippe-Longueville, Hars, Debois, & Calmels, 2009). Meanwhile, combined cognitive perceptual learning and physical practice has been assessed to be most efficient (Frank, Land, & Schack, 2015; Ingram, Kraeutner, Solomon, Westwood, & Boe, 2016). However, practical approaches on teaching strategies that aim for enhanced motor imagery abilities remain to be elucidated in the context of gymnastics (Simonsmeier & Frank, 2016).

In order to explore promising teaching methods to accelerate gymnastics skill learning in physical education, augmented feedback is suggested as an utterly important methodological resource to provide critical information (Schmidt & Lee, 2011; Veit, Jeraj, & Lobinger, 2016). In addition to the inherent feedback that learners gain through various sensory information during movement execution (Schmidt & Lee, 2011), gymnastics teachers may use different types of augmented feedback to positively affect the performance of students with little or no gymnastics experience (Lee, Keh, & Magill, 1993). On principal, a fundamental distinction is made between focussing on the outcome (knowledge of results) and the characteristics of a movement (knowledge of performance) while providing feedback (Schmidt & Lee, 2011). Augmented feedback traditionally is given by using verbal cues (Phillips, Farrow, Ball, & Helmer, 2013), in gymnastics commonly accompanied by tactile information (Gerling, 2009). Previous research dealing with effective teaching has recommended pertinent verbal instructions as being helpful in skill learning (e.g., Housner, 1990). Furthermore, with respect to the present study’s link to postural control patterns, the studies by Rogers, Wardman, Lord, and Fitzpatrick (2001) as well as by Krishnamoorthy, Slijper, and Latash (2002) have shown that tactile sensory input as a feedback concept decreases postural sway in erect stance. Aiming for providing knowledge of performance, the feedback should, for example, illustrate the characteristics of the correct movement by giving verbal and tactile information to contract the most important muscles. Additionally, giving augmented visual information (e.g., by video feedback) is a well-established teaching method that is suggested to enhance observational learning in early phases of motor skill acquisition by providing an image of the movement to the learner (Schmidt & Wrisberg, 2008). Taking into account that model observation has been reported to induce motor response by internal visual representation of the observed movement (Krause & Kobow, 2013), video feedback has been suggested to benefit the physical performance of novices in particular (Darden & Shimon, 2000). Considering that successful feedback is suggested to contain corrective targeted information (Horton & Deakin, 2008), visual information related to knowledge of results should show an expert model (Magill, 2014) performing the skill in excellent execution. However, there is evidence that observing an unexperienced novice is more beneficial to skill learning (Lee & White, 1990). In view of these contradictions, Rohbanfard, and Proteau (2011) suggest a mixed model approach including the visual comparison of an expert and a novice performing the movement in order to ensure a reference of correctness (Schmidt & Lee, 2011).

With regard to the literature, research dealing with practical applications of augmented feedback in gymnastics is rare, in particular referring to handstand performances. Masser (1993) observed that one critical verbal cue (i.e., “shoulders over your knuckles”) can be useful to assist practicing a process of learning the handstand in young children. Ghavami, Hosseini, and Mohammadzadeh (2012) suggest that observation of an animated model is more effective than verbal instructions to enhance students’ handstand balance. Moreover, observational training is suggested to enhance handstand skill performance one hour after practicing when combined with verbal instructions (Maleki, Nia, Zarghami, & Neisi, 2010). It is further reported that light fingertip contact on the lateral sides of the gymnast’s thigh supports balance in inverted stance (Croix, Lejeune, Anderson, & Thouvarecq, 2010). Taking these studies into consideration, the knowledge on feedback-induced changes of motor behaviour and motor imagery in gymnastics is still incomplete. It has to be considered that the above-mentioned reports used, for example, three-weeks research approaches (Ghavami et al., 2012; Masser, 1993) including combined movement practicing and feedback. Although the combination of feedback with physical practice is required to progress in motor learning in gymnastics (Shea, Wright, Wulf, & Whitacre, 2000), it is not finally clarified if observed motor behavioural changes are due to the received feedback. Up to now, there is no evidence revealing explicit practical recommendations for gymnastics teachers or coaches answering the question how to accelerate motor learning during physical practice of the handstand by using different augmented feedback concepts.

Therefore, the purpose of this study is to investigate a short-term influence of two different types of feedback (i.e., tactile-verbal feedback, TVF vs. visual-comparative feedback, VCF) on the enhancement of handstand postural performance and motor imagery in less-experienced novices. With respect to the reported benefits of observational learning in less-experienced learners (e.g., Ghavami et al., 2012; Schmidt & Wrisberg, 2008; Darden & Shimon, 2000), it is hypothesised that (1) VCF compared to TVF is more effective to enhance the quality of handstand postural performances and (2) the motor imagery of the handstand posture. It is further hypothesised that (3) enhancements in postural performance correlate with enhancements in motor imagery.

METHODS

Twenty-six healthy and uninjured volunteering Sport and Exercise Science students (7 females, 19 males) with no particular history in gymnastics other than a school or university class were recruited. Following randomisation (i.e., drawing numbers), participants were assigned into two matched feedback groups; group 1: tactile-verbal feedback (TVF, *n* = 13; age: 22.7 ± 3.9 years; height: 180.9 ± 9.2 cm; weight: 74.4 ± 10.2 kg), group 2: visual-comparative feedback (VCF, *n* = 13; age: 21.9 ± 1.8 years; height: 175.9 ± 9.7 cm; weight: 69.9 ± 13.9 kg). Advanced and competitive gymnasts were excluded. However, participants should be able to perform the lunge entry and upward swing to handstand (Johnson and Garcia, 1976) irrespective of the technique level. All randomised participants completed the exprimental procedure. In Accordance with University Ethics Committee, all participants obtained written informed consent.

Except for the feedback, all participants underwent the same experimental protocol wearing tight and dark sport clothes. Experiments were set up as single appointments, lasting approximately 30 min. Prior to a 10-min warm up (excluding any type of handstand to prevent preparatory learning), all participants received general welcoming instructions. Following warm up, marker points, selective to the present study's content-related joints, were set at anatomical landmarks; 1: knee at capitulum fibulae, 2: hip at iliac crest tuberculum, 3: shoulder at posterior deltoid, 4: head at temple hole between eyes and ear, and 5: wrist at processus styloideus ulnae.

Prior to performing their own handstands, a video showing an expert model demonstrating a technical guideline and referring to 'the perfect handstand' was shown to all participants twice (at first in real-time, secondly in slow-motion). Subjects were informed that the quality of their handstand posture is the key aspect they should focus on. In contrast to previous setups (e.g., Maleki et al., 2010), the model observation was left uncommented to have each participant evolve a self-reliant understanding on how to perform their upcoming best possible handstand posture. Subsequently, participants performed a single test trial of swing up to handstand to familiarise with the set up properties and conditions in the gym.

Following familiarisation, the pre-test examination started. Each participant was asked to perform three trails of handstand, encouraged to accomplish a high-quality bodyline. They were allowed to leave handstand in different manners, for example, roll down or place their feet back the way they started the lunge entry. After each of the three pre-test trials, participants immediately had to adjust content-related joints in a motion-doll (i.e., head, shoulder, hip; figure 1) in order to assess motor imagery of performed handstand posture. After each participant finished the doll adjustment, a photo of this doll-position was taken from a standardised bird's eye perspective. Following this procedure, participants received either the tactile-verbal feedback or the visual-comparative feedback before repeating another set of three handstands, the post-test.

Feedback 1 - tactile-verbal (TVF): Uzonov (2008) specifies several agonist muscle groups including their function for maintaining the correct handstand posture. Rounding the back and the posterior pelvic tilt are mentioned as essential actions (Uzonov, 2008). The posterior pelvic tilt is predominantly achieved by contraction of musculus rectus abdominis. Rounding the back comes along with shoulder girdle abduction by contracting musculus serratus anterior and musculus pectoralis minor. Additional to abduction, shoulder girdle elevation by musculus rhomboideus, musculus trapecius and musculus levator scapulae is also necessary to keep the well-balanced handstand. In order to focus on selected critical cues, posterior pelvic tilt, rounding the back and the shoulder girdle elevation were chosen for TVF. To implement TVF, participants simulated handstand position alignment while lying in a supine position on a gymnastics mat with arms straight and parallel next to the ears (if possible: shoulder angle = 180°). Maintaining this position, participants were requested to contract special muscles, which are crucial in order to optimise handstand posture. For this purpose, each participant received identical standardised instructions (Table 1). Tapping respective muscles with a pointer baton provided tactile feedbacks.

Table 1
Standardised tactile-verbal feedback (TVF).

Feedback	Tactile feedback	Verbal feedback
1	musculus gluteus maximus	“rotate your pelvis – flatten your back”
2	sternum	“chest in”
3	(pulling the hands)	“push upwards – make yourself tall”

Feedback 2 - visual-comparative (VCF): individual handstand trials were shown to the VCF-group via video. Using a modified mixed model approach (Rohbanfard & Proteau, 2011), participants were requested to find posture deficits by comparing their own trial with a screenshot of the expert model. Individual trial videos were demonstrated twice in chronological order without any commenting by the test operators, thus, there was no specific indication for the participants where to give the focus of attention.

Other than a laboratory examination, this study aimed at a user-oriented applied setting in the gym to simulate a familiar training atmosphere known from practice and physical education. With respect to the literature, large body joints provide information about handstand quality (e.g., Kerwin & Trewartha, 2001; Uzonov, 2008). In order to limit on essential handstand criteria relating to target group-specific skill abilities, this investigation focussed on the measurement of two large body joints being the shoulder and hip and including the head position as a handstand-related aesthetic feature (Gerling, 2009). Joint angles were specified as shown in Figure 1.

The primary outcome measure was a goniometric investigation, performed with the Kinovea analysis software version 0.8.15. Participants‘ trials were recorded on sagittal plane by a standard commercial mobile phone camera (Samsung Galaxy S5 mini) to examine body posture using economic equipment that may be purchased by teachers and coaches as well. Screen shots of handstand posture at its defined optimum were made to measure joint angles (head-position, shoulder, and hip). Inspired by Masser (1993), optimum handstand positions (i.e., screen shots taken) were defined based on the following criteria:

The participant rolled over: optimum was set where the participants’ feet reached their highest point

The participant placed their feet back in the direction where they started: optimum was set at the moment when the movement was reversed

Trial was excluded if handstand posture was not apparent (deviation more than 45° from vertical line between hands and feet at movement reversal point)

Postural performance was assessed by measuring and comparing joint angles of each participants’ handstand posture to the expert model handstand posture. Evaluation of motor imagery was examined by adjusting motion-dolls’ joint angles and comparing to participants**’** real handstand posture.

Statistical analysis was performed using SPSS for windows (version 22.0). Prior to conducting pairwise comparisons for each angle (i.e., head, shoulder, hip) to display pre to post differences in postural performance and motor imagery, the data was checked for normality. Based on this, either paired-samples *t*-tests or Wilcoxon signed-ranks tests compared pre to post differences for each group. Defectively collected data from two participants had to be excluded from analysis. Thus, a sample size of $n = 24$ ($n = 12$ for each group) was remaining. Data in the figures and tables are presented as mean (*M*) ± standard deviation (*SD*). The level of significance was set at $p < .05$; trends were accepted for $p < .10$.

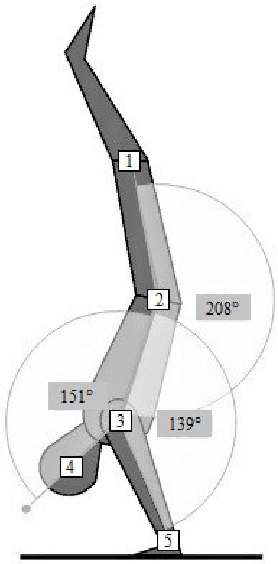

Figure 1. Goniometric analysis of handstand postural performance and motor imagery (joint angle definition in relation to the marker point numbers): shoulder, 2-3-5; hip, 1-2-3; head, 2-3-4).

RESULTS

Results of postural performances and motor imagery are presented for head, shoulder and hip positioning. Feedback-induced pre to post changes on angular deviations are displayed in figure 2 and table 2. Subsequently, correlating results are presented.

Postural performance

1. Head

Wilcoxon signed-ranks test revealed no significant pre to post differences in the TVF group, $Z = 0.63$, $p = .53$, $d = .17$. Further, paired-samples *t*-test showed no significant pre to post differences in the VCF group, $t(11) = -0.78$, $p = .45$, $d = .21$ (Table 2).

2. Shoulder

Wilcoxon signed-ranks test revealed significant increased shoulder angle performances in the TVF group, $Z = 2.70$, *p*

< .01, *d* = -.43. Further, paired-samples *t*-test showed that the shoulder angle performance increased by trend in the VCF group, *t*(11) = 1.91, *p* = .08, *d* = -.29 (Figure 2A; Table 2).

3. Hip

Wilcoxon signed-ranks test revealed no significant pre to post differences in the TVF, *Z* = 1.18, *p* = .24, *d* = .21, and the VCF group, *Z* = 0.24, *p* = .81, *d* = -.06 (Table 2).

Motor imagery

1. Head

Paired-samples *t*-test revealed no significant pre to post differences in the TVF, *t*(11) = -0.67, *p* = .52, *d* = .12, and the VCF group, *t*(11) = 0.02, *p* = .99, *d* = -.01 (Table 2).

2. Shoulder

Wilcoxon signed-ranks test revealed no significant pre to post differences in the TVF group, *Z* = 0.71, *p* = .48, *d* = -.18. However, paired-samples *t*-test obtained significant increased motor imagery of the shoulder joint in the VCF group, *t*(11) = 2.65, *p* = .02, *d* = -.96 (Figure 2B; Table 2).

3. Hip

Wilcoxon signed-ranks test revealed no significant pre to post differences in the TVF, *Z* = 0.16, *p* = .88, *d* = .06, and the VCF group, *Z* = 0.47, *p* = .64, *d* = -.19 (Table 2).

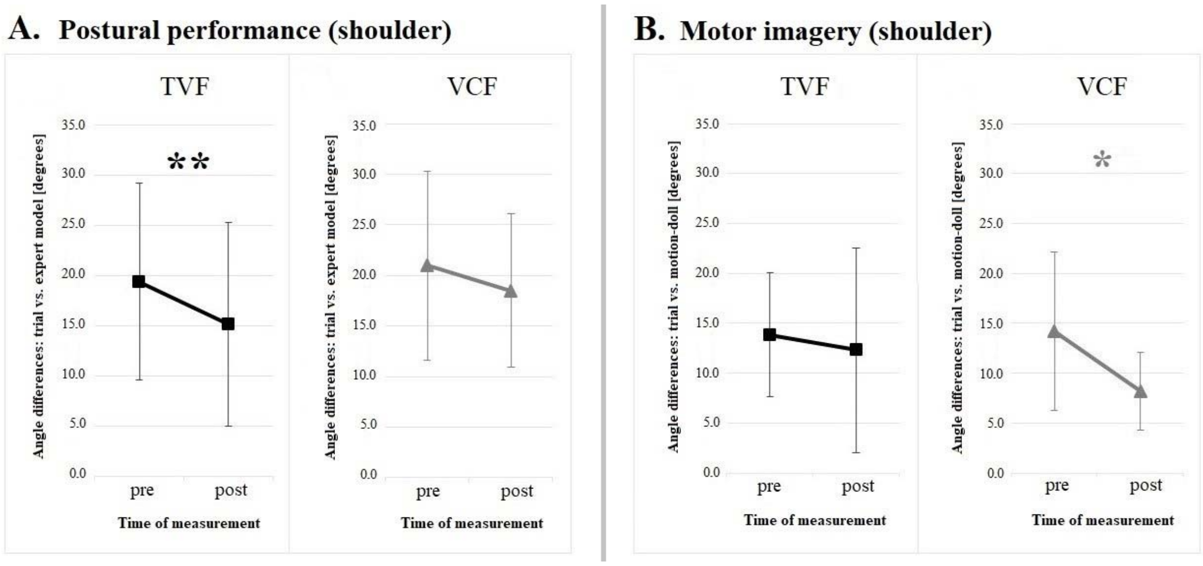

Figure 2. (A) Displayed are shoulder angles for pre to post differences between ideal handstand and handstand trial in the TVF and the VCF group. (B) Displayed are shoulder angles for pre to post differences between handstand trial and motion-doll adjustment in the TVF and the VCF group. Lines depict group average differences between pre- and post-test with *SD* error bars. Level of significance: **p* < .05; ***p* < .01.

Table 2
Feedback-impact on handstand postural performance and motor imagery.

		Postural performance				Motor imagery			
Feedback	Angle	Pre (M ± SD)	Post (M ± SD)	*p*	Cohen's *d*	Pre (M ± SD)	Post (M ± SD)	*p*	Cohen's *d*
TVF	head	27.30 ± 14.01	29.63 ± 13.92	.53	.17	31.08 ± 15.60	32.87 ± 14.49	.52	.12
	shoulder	19.38 ± 9.80	15.13 ± 10.15**	< .01	-.43	13.83 ± 6.21	12.33 ± 10.26	.48	-.18
	hip	10.03 ± 5.12	11.26 ± 6.63	.24	.21	15.48 ± 11.10	16.18 ± 12.06	.88	.06
VCF	head	17.51 ± 10.67	19.84 ± 11.21	.45	.21	23.17 ± 14.01	23.10 ± 14.63	.99	-.01
	shoulder	20.97 ± 9.38	18.53 ± 7.55	.08	-.29	14.20 ± 7.92	8.20 ± 3.92*	.02	-.96
	hip	9.94 ± 7.14	9.55 ± 6.45	.81	-.06	15.87 ± 14.78	13.69 ± 6.77	.64	-.19

M: mean value; *SD*: standard deviation; Level of significance: *$p < .05$; **$p < .01$

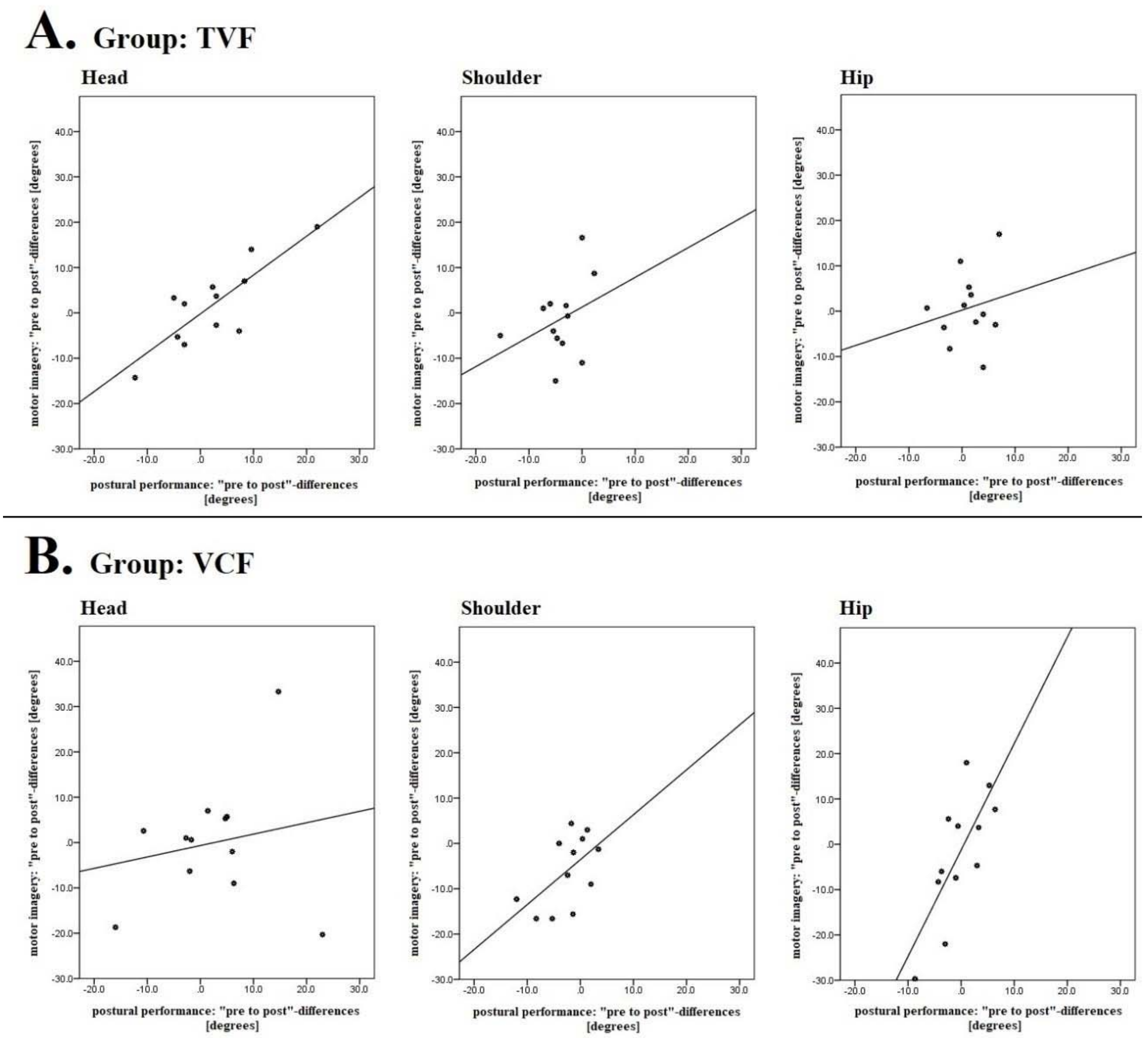

Figure 3. Correlations between the pre- to post-changes in postural performance and motor imagery within head, shoulder and hip positioning in the TVF and the VCF group.

A correlation analysis revealed a significant correlation for postural performance and motor imagery, $r(70) = .48$, $p < .001$. Further, there is a significant correlation between postural performance and motor imagery for TVF, $r(34) = .56$, $p < .001$, and a significant trivial correlation for VCF, $r(34) = .39$, $p < .02$. TVF: Significant correlations between postural performance and motor imagery were found for head position, $r(10) = .83$, $p < .01$, but not for shoulder angle, $r(10) = .35$, $p = .27$, and hip angle, $r(10) = .20$, $p = .54$ (Figure 3A). VCF: Significant correlations between postural performance and motor imagery were found for hip angle, $r(10) = .75$, $p < .01$, but not for head position, $r(10) = .19$, $p = .56$, and shoulder angle, $r(10) = .35$, $p = .27$ (Figure 3B).

To summarise, main findings revealed enhanced postural performance of shoulder positioning following TVF, whereas shoulder motor imagery is enhanced following VCF; postural performance and motor imagery correlated with head positioning following TVF and with hip positioning following VCF.

DISCUSSION

In view of handstands' importance in gymnastics (e.g., Uzonov, 2008; Hedbávný et al., 2013; Johnson & Garcia, 1976) and the role of augmented feedback in motor learning and physical education (Housner, 1990; Lee et al., 1993; Magill & Anderson, 2012; Veit et al., 2016), the present study aimed to discover short-term effects of standardised tactile-verbal feedback (TVF) vs. visual-comparative feedback (VCF) on handstand postural performance and motor imagery. The main findings were that postural performance enhanced in the shoulder angle after TVF, whereas VCF enhanced imagery of the shoulder angle. Furthermore, changes in postural performance and motor imagery correlated in head (i.e., TVF) and hip positions (i.e., VCF). However, changes in other joint angles were not statistically significant.

In the present study, handstand postural performance was significantly enhanced in the shoulder angle after TVF, but not following VCF. These findings contradict the present study's initial hypothesis (1) assuming an enhanced alignment of the handstand posture following visual information. Participants who received a modified observational learning comparing their pre-test handstand trials to the ideal handstand of the expert model (Lee & White, 1990; Magill, 2014; Rohbanfard & Proteau, 2011) only enhanced shoulder angle positioning by trend. Thus, these findings are contradictory to previous research suggesting video feedback and observational learning to accelerate novices' learning of motor tasks or even handstand acquisition (Darden & Shimon, 2000; Ghavami et al., 2012; Schmidt & Wrisberg, 2008). While this research used a visual feedback concept without additional verbal instructions, previous (gymnastics-specific) motor behavioural research displayed enhanced motor learning using combined (visual and verbal) feedbacks (e.g., Maleki et al., 2010). Additionally, with respect to the short time period between the pre- and post-tests, missing time for visuomotor processes and movement representation (Jeannerod, 1994; Krause & Kobow, 2013; Noth, 2012; Schack & Mechsner, 2006) might further explain why no better performances were observed after VCF. Moreover, the participants' focus of attention while receiving VCF has not been clarified. Due to the fact that successful feedback is suggested to contain corrective targeted information (Horton & Deakin, 2008), participants who observed their own handstand trial predominantly instead of comparing themselves to the expert model might have achieved worse postural performance results.

Nevertheless, the present findings are in line with well-accepted practical knowledge about beneficial effects of verbal and tactile information on motor learning and postural movement patterns (Croix et al., 2010; Housner, 1990; Krishnamoorthy et al., 2002; Masser, 1993; Phillips et al., 2013; Rogers et al., 2001). Thus, critical cues as well as tactile stimulation are presumed to even support short-term enhancements in handstand motor behaviour (Croix et al., 2010; Masser, 1993; Rogers et al., 2001). However, in this study, the enhancement of postural performance after TVF only applied to the shoulder joint angle, but not to hip joint angle and head position. Irrespective of possible lacks of physical aspects, for example insufficient core stability to hold the hip in place, these findings add to current biomechanical results revealing that shoulder torque plays a more important role than hip torque in postural control mechanisms of the handstand (Kerwin & Trewartha, 2001; Mohammadi & Yazici, 2016; Yeadon & Trewartha, 2003). With respect to the less influential role of the hip torque for decreasing postural disturbances (Gautier et al., 2007), this might explain why no better hip postures were observed after TVF. Although the participants were instructed to focus on the quality of joint angles instead of aiming at a long-lasting handstand, they, primarily and implicitly, seemed to aim at balancing the centre of mass in equilibrium. With regard to the knowledge about an “ankle strategy” and a “hip strategy” in upright stance (Runge et al., 1999), gymnasts’ hip joints appear to remain relatively uncoordinated and arbitrary as long as wrists’ and shoulders’ work predominantly to regulate postural balance (Gautier et al., 2009). Thus, it can be further discussed whether a different research approach including wrist work is needed. However, our results provide reasons to support earlier findings that handstands’ postural control is based on a postural regulation system similar to that in upright stance (e.g., Gautier et al., 2007; Hedbávný et al., 2013; Kerwin & Trewartha, 2001; Mohammadi & Yazici, 2016) that obviously has to be considered for providing pertinent feedback.

Furthermore, handstand motor imagery was enhanced in the shoulder angle following VCF, but not following TVF. Supporting the present study’s second hypothesis (2), these results are in line with previous motor behavioural research and confirmed findings concerning the beneficial effects of video feedback on novice gymnasts’ internal visualisation of motion and posture (Darden & Shimon, 2000; Schmidt & Wrisberg, 2008). However, VCF has not been shown to positively affect motor imagery of other joint angles (i.e., hip, head), which is in conflict to our hypothesis (2). Missing time for developing a relationship between observed kinematical aspects and a motor representation of the movement might serve as an explanation (Jeannerod, 1994; Noth, 2012; Schack, 2003; Schack & Mechsner, 2006); however, this again raises the question why shoulder imagery enhanced. In order to interpret the findings for the hip joint, another approach has to be taken into account challenging whether poor or good trials (or even both) could not be mentally visualised. Based on the underlying assumption that motor imagery of perturbed hip and head stabilisations was defective, the loss of (visual) orientation during erroneous head positioning caused by insufficient experience in handstands might obstruct good motor imagery despite visual feedback. With respect to presumed handstand postural control mechanisms (Gautier et al., 2007; Kerwin & Trewartha, 2001), one explanation for the absent benefit in the hip joint while receiving VCF might be the less influential role of this joint for postural control in handstands. There are reasons to believe that, in case of insufficient muscular triggering of the hip, defective cognitive processing that fails to combine inherent and augmented feedback information (Schmidt & Lee, 2011) makes it more difficult to develop motor imagery of the hip positioning. However, these interpretative approaches can only be presumed owing the lack of according evidence that has to be addressed by future studies.

Moreover, in the TVF group, the performance of head position correlated with motor imagery of the head position. In the TVF group, participants’ performance and motor imagery was unaffected by visual information. Furthermore, participants were not given a standardised tactile-verbal instruction concerning the position of the head. With regard to the present study's third hypothesis (3) assuming accompanied enhancements in motor behavioural and motor imagery efforts (d'Arippe-Longueville et al., 2009; Frank et al., 2015; Ingram et al., 2016; Noth, 2012; Schack, 2003; Schack & Mechsner, 2006; Simonsmeier & Frank, 2016), reasons for this finding have to be discussed. It seems reasonable to assume that, on the one hand, TVF participants consciously perceived positive changes in head position performance due to feeling their shoulders next to their ears while performing the handstand (Uzonov, 2008), considering that similar sensory information during handstand are missing for the shoulder and hip joint. As reported above, while receiving TVF, the participants were asked to place their arms straight and parallel next to their ears. This light sensory information (Krishnamoorthy et al., 2002; Rogers et al., 2001) indicating an enhanced aligned head positioning (Gerling, 2009) might sensitise learners for the correct head postion and, thus, increase participants' motor imagery of this postural enhancement what is reflected in the corrected adjustment of the motion-doll. On the other hand, if this sensory input is not received as it occurs in less successful handstand performances, motor imagery of the head positioning is assumed to be much more difficult for less-experienced novices. Thus, for future studies it is suggested to challenge the question whether tactile feedback to the head affect motor behaviour in novel gymnasts. In light of the present study's findings, the matter of teaching the head positioning in handstands remains to be elucidated in additional research.

In the VCF group, the present study detected a correlation between postural performance and motor imagery for hip angle, but not for shoulder angle and head position. In light of these findings, absent correlations for shoulder and head positioning might be explained by the study of Shea et al. (2000) showing that observational training is less effective than physical practice, considering that the benefits of observational practice can only be exploited by alternating observational with physical practice (Shea et al., 2000). However, obtained correlations for the hip joint have to be discussed. Taking into account that impaired (respectively enhanced) hip joint performances seem to be accompanied by poor (respectively good) motor imagery results, contrasting observation of the expert model compared to the learners handstand seems to focus the hip joint, presumably due to the fact that good postures concerning the largest involved body joint are particularly apparent. However, these findings are in line with the previously discussed assumption that perturbed hip positioning is difficult to perceive. Accordingly, with respect to the model of handstand postural control and with respect to previous discussed findings regarding motor imagery of the hip joint in VCF, mental visualisation of the hip joint (what is minor utilized to balance handstand posture) seems to be challenging in the presence of postural sway. In view of absent correlations in shoulder and head positioning after VCF, perception of actual perturbations in these body segments varied arbitrarily. However, these thoughts have to be investigated in future research to clarify the present study's third hypothesis (3). In particular, future studies should challenge the question if (visual) feedbacks' efficiency depends on the relevance to perform motor skills in certain parts of the body.

In summary, with regard to postural regulation patterns in inverted stance, the obtained data indicate TVF to positively affect the shoulder angle, but not the hip angle and head regulation in handstand performances. Despite marginally enhanced shoulder positioning in VCF, missing verbal cues and an assumed inappropriate attentional focus might explain absent postural enhancements following VCF. Apart from enhanced shoulder angle imagery after receiving VCF, lacking orientation (i.e., head) and insufficient inherent feedback (i.e., hip) due to occurred postural sway presumably impeded further benefits of VCF in motor imagery. Furthermore, tactile contact between shoulders and ears received in TVF is suggested to provide sensory feedback enabling novices' self-control in aligned head positioning. As these findings have obtained a complexity for providing augmented feedback efficiently, future studies should continue approaching applied research focussing on the optimal sensory input with the objective on accelerating novices' motor learning and, thus, skill acquisition.

CONCLUSIONS

The present study revealed enhanced shoulder positioning in handstands after TVF, whereas motor imagery of the shoulder angle enhanced following VCF. The findings suggest commented tactile feedback to be beneficial for short-term increases of handstands' postural quality; however, video feedback is useful to provide short-term corrected motor imagery of the handstand posture. Taken together, this study confirmed the importance of augmented feedback in acquisition of motor skills suggesting sensory information to assist accordance between postural performance and motor imagery in handstands. To conclude, in order to accelerate progressing handstand acquisition in early stages of learning, different types of feedback effect several issues of motor learning in different manners, but even in a short-term approach and without the influence of physical practice. Thus, practical recommendations are suggested to consider combined feedback concepts that mutually provide tactile-verbal as well as visual information to allow comprehensive motor learning in less-experienced learners.

LIMITATIONS

Retrospectively, we are well aware that the missing of finger and wrist work appears to be important to discuss findings on postural performance. However, in view of palms acting as interface between body and support surface (Kerwin & Trewartha, 2001), the hands represent a steady point, which does not affect the visual impression of varying handstand postures. Furthermore, due to the intentional focussing on the shoulder and hip joint, in this study ankle and foot work were left aside, although both might influence the actual knee joint position and the visual impression of the handstand in less-experienced learners. It also has to be taken into account that the used motion-doll can only be a mock-up, but not a template to represent a human body's proportions; however, this method turned out to be useful in this applied approach. In addition to this study aiming to examine differences between different feedback concepts, further research may include sufficient control conditions (e.g., no provided feedback at all), possibly adding valuable insights to the comparison of two impacting feedback concepts.

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