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Acquisition of the Long Jump Skill Using Varying Feedback

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Abstract

The aim of this study was to examine the acquisition of the long jump skill in elementary school children using augmented feedback of varying type and frequency. Eighty-eight boys and girls aged (mean ± SD) 11 ± 0.5 years, without any prior experience in the long jump skill acquisition, were assigned to one of the four study groups: (1) the group receiving only verbal feedback on key errors, (2) the group receiving both verbal and video feedback on key errors, (3) the group receiving both verbal and video feedback on all errors, and (4) the group receiving no feedback. Before and after an 8-week training intervention, long jump distance and relevant kinematic variables were recorded. The results indicated that the group receiving both verbal and video feedback on all errors improved the most in terms of the long jump distance. Varying feedback influenced kinematic parameters differently, as there was no consistent change in the monitored kinematic variables across groups. It was concluded that when learning a complex motor skill in a typical Physical Education setting, elementary school children are likely to benefit the most when receiving frequent feedback (both verbal and using video analysis, focusing on all errors), in comparison with the situation in which they receive feedback reduced in the type (only verbal) and the frequency (focusing only on key errors).

Keywords: *bandwidth feedback; kinematics; knowledge of performance; motor learning.*

Introduction

The process of motor learning produces changes in internal processes that determine a person's capability of producing a motor task. One of the essential ways practitioners can influence the learning process is by providing people with feedback on their actions. This type of feedback is called extrinsic or augmented feedback (Schmidt &

Wrisberg, 2004). Knowledge of results (KR) and knowledge of performance (KP) are two subtypes of augmented feedback. KR is given immediately upon completion of the task, and it often refers to verbal information about .the degree of fulfilling the task itself. KP is given the same way as KR but can consist of verbal and visual information regarding movement patterns. A more descriptive term for KP is augmented kinematic feedback; such information refers to aspects of position, velocity, or acceleration of the limbs, frequently as a function of time, and may include information about the actions of the limbs concerning each other (Schmidt & Young, 1991). This type of feedback is commonly used in practice when learning a complex motor skill. There are several different forms of presenting KP to the learner: verbal descriptive KP (error only), verbal prescriptive KP (error and correction), video replays of skill performances, movement kinematics and kinetics associated with an attempt to perform a skill and biofeedback (Magill & Anderson, 2014). Moreover, giving feedback during or after every practice trial represents 100% of feedback frequency; other strategies may consider reducing it.

Studies on feedback frequency show that practice in conditions with reduced feedback is more effective than high-frequency feedback while learning simple motor tasks, such as arm movement to a specific position, producing a certain amount of force (Lee & Carnahan, 1990; Winstein et al., 1994; Park et al., 2000; Agethen & Krause, 2016), or those which include depressing the buttons in the prescribed sequence (Wulf et al., 1994; Badets & Blandin, 2010). The main focus of those studies is on relatively simple motor skills restricted to the laboratory environment. Transferring the conclusions of those studies to motor skills that are more complex and included in natural sports settings is not entirely possible; therefore, the generalizability of those results has been called into question (Wulf & Shea, 2002). However, some findings support hypothesis that reduced feedback has a beneficial effect on a complex motor task such as chipping the golf ball (Smith et al., 1997), target shooting with a soccer ball (Wulf et al., 2002) and throwing a saloon dart (Coca-Ugrinowitsch et al., 2014).

Contrary to the findings listed above, there is evidence that high-frequency feedback is a better strategy to use when learning a novel simple or complex motor skill (Wulf et al., 1998; Fujii et al., 2016), but only in acquisition, while the learning effect of high-frequency feedback in retention could disappear (Mononen et al., 2003). According to the guidance hypothesis, concurrent feedback degrades influence on motor program accuracy and stability (Schmidt & Wulf, 1997). All the studies on feedback frequency listed above included young adults as participants, and there is little evidence that conclusions made on adults could apply to children. Some studies conducted involving children showed that less frequent feedback can be better: a study on learning the soccer throw-in skill concluded that 33% relative frequency of KP is better than 100% (Weeks & Kordus, 1998), and a more recent study on tossing bean bags to a target had similar findings (Zamani & Zarghami, 2015). However, Goh et al., (2012) stated that children, compared to adults, respond to feedback frequency differently during motor skill acquisition. In their research, feedback faded gradually throughout the experiment and the authors concluded that children were able to learn movement parameters as effectively as adults only when receiving feedback after every practice trial, which is in line with statements that children benefit from more frequent feedback, compared to reduced frequency feedback (Chiviacowsky et al., 2008). Besides et al. (2008) suggest that feedback given to children should be reduced more gradually throughout practice because decreasing feedback frequency beyond a critical point during the acquisition phase is detrimental to motor performance and learning. Especially interesting are the latest studies on children who utilize bandwidth feedback (BF) in learning complex motor skills in natural settings. Those studies had shown that BF with wide bandwidth could be the way to go (Ugrinowitsch et al., 2010; Sadowski et al., 2013). BF is a technique that reduces feedback so that it is given to learners only when their errors exceed a certain tolerance level (Schmidt & Wrisberg, 2004). While learners receive information about errors, they should, at the same time, be aware that no feedback means good performance, which might explain why giving frequent feedback early in practice and infrequently later is both an effective strategy and one that occurs as a natural consequence of the bandwidth procedure (Lee et al., 1994).

Combining verbal and visual KP (kinematic feedback) is a method often used in practice. Giannousi and Kioumourtzoglou (2017) showed in their study that a combination of verbal and visual feedback on novice swimmers is more effective than the verbal alone; even more, it is wrong to believe that only KP should produce the best results (Niznikowski et al., 2016).

In this research, we hypothesize that a reduced BF-based, augmented feedback is more effective compared to the more frequently provided augmented feedback for children learning a complex motor skill in a typical Physical Education setting, and that a combination of verbal and visual KP produces more effective outcomes in terms of skill acquisition in comparison with mere verbal KP. The purpose of this experiment was to examine the acquisition of the long jump skill in children using different types of augmented feedback.

Methods

Participants

Eighty-eight boys and girls, elementary school students, with no prior training experience in the long jump initially participated in this study and, in the end, results of seventy-five participants entered data analysis. Poor attendance at training sessions (below 80%), not showing up on the final testing day, or being marked as an outlier (using an interquartile range) excluded thirteen participants. The research was approved by the Scientific and Ethics Committee of the Faculty of Kinesiology, University of Zagreb, Croatia, while children's parents provided written informed consent. Due to the prior existing groups in natural school settings (class groups), these groups were randomly assigned to one of three experimental conditions: verbal BF (Ve_BF, n=19), verbal and video BF (Ve+Vi_BF, n=24), verbal and video 100% feedback (Ve+Vi_100%, n=14), and the control group (Con, n=18). Because this study was conducted in a natural school setting (i.e., a Physical Education class), a completely randomized study design was not used due to the potential interaction between participants. For example, participants in the control group could hear verbal cues intended only for the experimental groups.

Variables

The experimental condition was an independent variable which varied in feedback frequency and feedback type across the four groups: verbal feedback on key errors (Ve_BF), verbal and video feedback on key errors (Ve+Vi_BF), verbal and video feedback on all errors (Ve+Vi_100%) and no feedback – practice only (Con). Long jump technique was a dependent variable described by the effective distance (D_{eff}) of the long jump, as well as the following kinematic parameters: horizontal velocity of the center of gravity (CG) at the instant of touch-down (VX_{td}), CG resultant velocity at the end of take-off (VR_{to}), take-off duration (T_d), take-off angle (A_{to}), maximum knee flexion angle (A_{mkf}), inclination angle at the instant of touch-down ($A_{i\text{-}td}$) and inclination angle at the end of take-off ($A_{i\text{-}to}$). As the take-off is the central part of the long jump, kinematic parameters describing the take-off were selected because jumpers must, in order to obtain upward momentum, exert a downward impulse on the ground (Alexander, 1990).

Apparatus and task

Participants underwent standardized initial and final testing in the track and field hall. They were allowed to make four jumps using a 15 to 20-meter approach, using one leg to push off and land on their both feet into the sandpit. We obtained D_{eff} using a take-off zone (1x1m) in front of the sandpit. The take-off zone was sprinkled with a thin film of white chalk to establish a proper take-off mark (toe line). We extended this mark, so it was perpendicular to approach direction and thus made it possible to measure the distance to the closet break mark in the sandpit (according to the World Athletics rules and regulations). All trials were measured using a steel measuring tape and filmed using two Sony HDR-HC9E camcorders operating at 50 frames per second (fps) and one Casio EX-ZR100 digital camera operating at 240fps. A 5-inch screen digital stopwatch showing time in minutes and seconds was positioned on the right side of the take-off zone to enable synchronization between camcorders and digital camera while performing a kinematic analysis. Camcorders were posted on the left side of the take-off zone under the angle of approximately 90 degrees and 5 meters away from it, with a digital camera in between, which was filming only the take-off foot. The best of four performances (D_{eff}) entered the 3D kinematic analysis. We performed kinematic data acquisition and processing, according to APAS (Ariel Performance Analysis System) procedure standards. Only take-off duration (T_d) was obtained from a 240fps camera using Kinovea video player for sport analysis. The first clear take-off foot-ground contact frame marked the beginning of the take-off, and the last visible contact marked the end.

Procedure

After initial testing, all participants completed 16 practice sessions arranged into eight weeks – two sessions per week according to their school Physical Education schedule. Before each practice, participants received a video demonstration of the task along with verbal guidance. After the presentation, each participant performed ten jumps, receiving verbal or verbal and video feedback on errors (or no feedback – Con), given by one of the two Physical Education teachers experienced enough to recognize an error and provide standardized feedback (Table 1). At first, participants were jumping using a 6-step approach, adding two steps after every four sessions, thus ending the last four sessions using a 12-step approach. This progressive method allowed participants to learn long jump skill at lower running speeds at the beginning.

Table 1

List of errors and verbal cues used by teachers

	M_{score}	Error	Verbal cue
1.	6.4	Inadequate approach running technique – landing on a heel or the entire foot while running	Run faster on the ball of the foot
2.	6.0	Front torso tilt at take-off	Keep the torso straight during take-off
3.	6.0	Incorrect foot plant at the beginning of the take-off – heel or toes first contact	Plant the take-off foot flat on the ground during take-off
4.	5.8	Back torso tilt at take-off	Keep the torso straight during take-off
5.	5.8	Landing on the straight legs (insufficient leg raise and no forward torso tilt)	Raise the legs and tilt the torso to the front while landing, bend the knees to soften the impact
6.	5.8	Legs are not parallel while landing (landing with feet apart)	Bring the feet together while landing
7.	5.5	Arms are placed behind the body while landing	Bring the arms forward while landing
8.	5.5	Unnecessary shortening of the last few strides of the approach	Maintain stride length to the end of the approach
9.	5.5	Bad lead knee swing while taking off	Forcefully swing the lead knee upward while taking off
10.	5.3	Progressive acceleration from the beginning to the end of the approach is missing	End the approach running faster than at the beginning of the approach
11.	5.1	Looking down to the take-off zone while taking off	Look ahead while taking off
12.	5.1	Significant loss of balance after take-off due to the inadequate limb action	Raise the legs and tilt the torso to the front while landing, bend the knees to soften the impact
13.	5.0	Inadequate arm swing during take-off	While taking off, swing the arms in the way which is normal while running
14.	4.8	There is no last stride shortening	Make the last stride shorter

NOTE. M_{score} – Mean score of each error graded by expert coaches.

The authors of this study established a list of 14 errors; 21 expert coaches graded each error using a questionnaire designed exclusively for this study. A Likert 7-point scale was employed, 1 being a not relevant error, and 7 being a key error while executing a long-jump technique by children. Top 3 errors were used in groups using the BF procedure and all 14 in 100% feedback group (up to 3 errors per jump). The authors defined verbal cues on errors before the experiment started (Table 1). Ve+Vi_BF and Ve+Vi_100% groups were receiving video feedback on their long jump execution on a computer monitor concurrently with verbal feedback, immediately after the jump.

Statistical analysis

The Shapiro–Wilk test calculated the normality of distribution and the homogeneity of variance of the pre- and post-intervention scores. After verification of normality and homogeneity of variance, and prior to running a multivariate analysis of variance (MANOVA), a series of correlation analyses were performed between all dependent variables to test the MANOVA assumption of no multicollinearity. The dependent variables were moderately intercorrelated ($r = 0.11 - 0.87$). Additionally, Box's M value of 162.28 combined with a significance of $p = 0.105$ indicated that the covariance matrices between groups were assumed to be equal. As all assumptions were met, MANOVA was used to test for any differences between the groups in the pre-intervention assessment. Since there were existing differences in the pre-intervention assessment, the analysis of covariance (ANCOVA) was used to examine the influence of the experimental treatment on kinematic variables using the pre-intervention measurements as covariate. Where ANCOVA was significant, Bonferroni post-hoc tests were used to assess the origin of the between-group differences. Prior to each ANCOVA, scatterplots were used to compare the regression lines, and our data met the assumption of homogeneity of regression slopes and all other ANCOVA assumptions.

To determine the magnitude of the within-group changes in the observed variables, an effect size (Cohen's d) was calculated. The effect sizes of ≤0.19, 0.20-0.49, 0.50-0.79, and ≥0.8 were interpreted as trivial, small, medium and large effect sizes, respectively. The significance of within-group changes was estimated using paired samples t-tests. The level of significance was set at $p<0.05$. Data are presented as mean ±SD or percentage change ±SD. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp. was used to carry out the statistical analysis.

Results

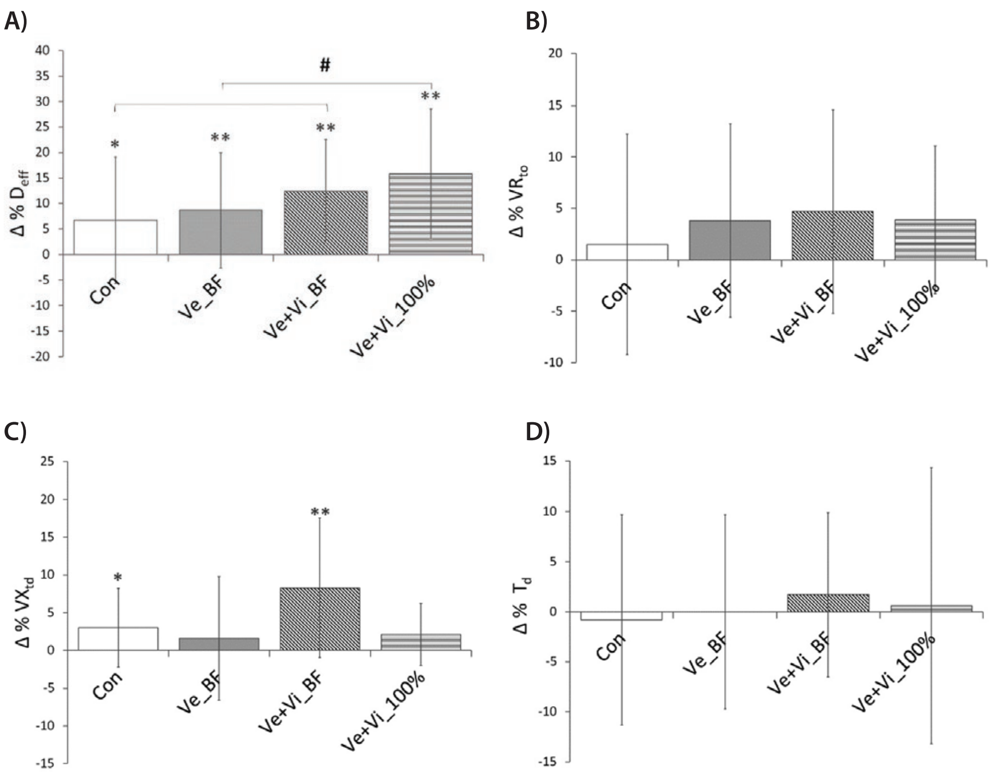
The MANOVA on pretest scores indicated significant differences among the groups ($p < 0.001$). Explicitly, initial differences were observed in the following kinematic parameters: the horizontal velocity of the CG at the instant of touch-down (VX_{td}, $p = 0.001$), take-off duration (T_d, $p = 0.006$), inclination angle at the instant of touch-down ($A_{i\text{-}td}$, $p = 0.003$) and inclination angle at the end of take-off ($A_{i\text{-}to}$, $p = 0.004$).

Table 2

Results of the ANCOVA for each variable followed by Bonferroni post-hoc test.

	ANCOVA	Bonferroni post-hoc
D_{eff}	p = 0.004	Ve+Vi_100% > Con (p = 0.004); Ve+Vi_100% > Ve_BF (p = 0.018); Ve+Vi_100% > Ve+Vi_BF (p = 0.038)
VR_{to}	p = 0.349	
VX_{td}	p = 0.145	
T_d	p = 0.253	
A_{to}	p = 0.011	Con > Ve+Vi_BF (p = 0.007)
A_{mkf}	p = 0.012	Con > Ve+Vi_BF (p = 0.025)
$A_{i\text{-}td}$	p = 0.207	
$A_{i\text{-}to}$	p < 0.001	Con > Ve+Vi_BF (p = 0.000); Con > Ve+Vi_100% (p = 0.002); Ve_BF > Ve+Vi_BF (p = 0.018)

NOTE. Con - no feedback; Ve_BF - verbal feedback on key errors; Ve+Vi_BF - verbal and video feedback on key errors; Ve+Vi_100% - verbal and video feedback on all errors; D_{eff} - effective jump distance; VR_{to} - CG resultant velocity at the end of take-off; VX_{td} - CG horizontal velocity at the instant of touch-down; T_d - take-off duration; A_{to} - take-off angle; A_{mkf} - maximum knee flexion angle; $A_{i\text{-}td}$ - inclination angle at the instant of touch-down; and $A_{i\text{-}to}$ - inclination angle at the end of take-off.



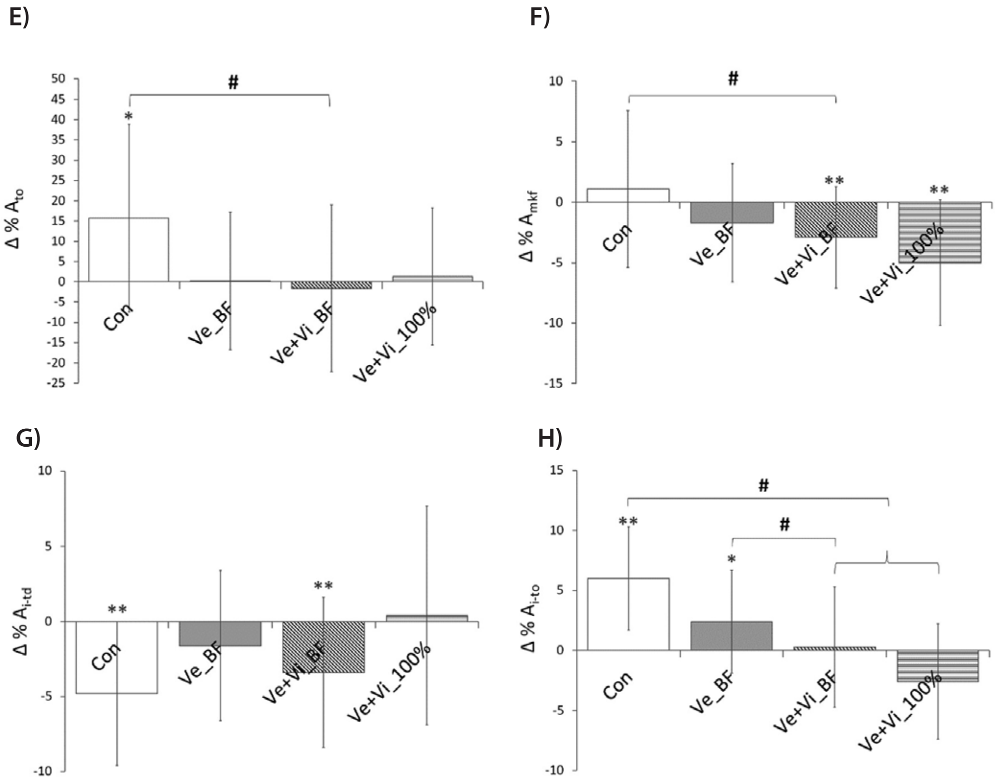


Figure 1. Relative changes (Δ %) from initial to final testing across all kinematic and performance variables – A) effective jump distance; B) CG resultant velocity at the end of take-off; C) CG horizontal velocity at the instant of touch-down; D) take-off duration; E) take-off angle; F) maximum knee flexion angle; G) inclination angle at the instant of touch-down; and H) inclination angle at the end of take-off.

NOTE. * statistically significant within-group change ($p < 0.05$); ** statistically significant within-group change ($p < 0.01$); # statistically significant between-group change

Statistically significant differences between groups, as determined by a series of ANCOVAs, were observed for the following variables (Table 2): effective jump distance (D_{eff}, $p = 0.004$), take-off angle (A_{to}, $p = 0.011$), maximum knee flexion angle (A_{mkf}, $p = 0.012$) and inclination angle at the end of take-off ($A_{i\text{-}to}$, $p < 0.001$). No significant differences were found across the four groups for CG resultant velocity at the end of take-off (VR_{to}, $p = 0.349$), CG horizontal velocity at the instant of touch-down (VX_{td}, $p = 0.145$), take-off duration (T_d, $p = 0.253$) and inclination angle at the instant of touch-down ($A_{i\text{-}td}$, $p = 0.207$).

Jump distance

All groups achieved statistically significant improvement in the long jump distance at the end of the intervention. Specifically, a 6.7 ± 12.4% improvement in Con ($d = 0.28$, $p = 0.041$), 8.7 ± 11.3% in Ve_BF ($d = 0.39$, $p = 0.003$), 12.4 ± 10.1% in Ve+Vi_BF ($d = 0.53$, $p < 0.001$) and 15.8 ± 12.8% in Ve+Vi_100% groups ($d = 0.61$, $p < 0.001$). Only the Ve+Vi_100% group outperformed all other groups (Table 2) in terms of the jump distance.

Table 3
Descriptive statistics (mean ±SD) of Pre- and Post- measurements and effect sizes.

		Con	Ve_BF	Ve+VI_BF	Ve+Vi_100%
N		18	19	24	14
Age		11.2 ± 0.3	11.0 ± 0.3	11.1 ± 0.3	12.1 ± 0.3
D_{eff} (cm)	Pre	283 ± 58	273 ± 55	249 ± 53	296 ± 71
	Post	297 ± 49	294 ± 49	277 ± 50	337 ± 59
	Cohen's d	d = 0.28 (p = 0.041)	d = 0.39 (p = 0.003)	d = 0.53 (p < 0.001)	d = 0.61 (p < 0.001)
VR_{to} (m/s)	Pre	5.1 ± 0.7	5.0 ± 0.8	4.8 ± 0.7	5.3 ± 0.6
	Post	5.1 ± 0.5	5.1 ± 0.6	4.9 ± 0.6	5.5 ± 0.7
	Cohen's d	d = 0.05 (p = 0.803)	d = 0.21 (p = 0.193)	d = 0.30 (p = 0.062)	d = 0.32 (p = 0.053)
VX_{td} (m/s)	Pre	5.4 ± 0.6	5.5 ± 0.6	5.2 ± 0.7	6.1 ± 0.7
	Post	5.6 ± 0.5	5.6 ± 0.6	5.5 ± 0.5	6.2 ± 0.6
	Cohen's d	d = 0.27 (p = 0.031)	d = 0.12 (p = 0.447)	d = 0.62 (p < 0.001)	d = 0.17 (p = 0.094)
T_d (ms)	Pre	173 ± 27	172 ± 25	197 ± 31	173 ± 21
	Post	170 ± 22	171 ± 24	200 ± 35	173 ± 25
	Cohen's d	d = -0.12 (p = 0.491)	d = -0.03 (p = 0.851)	d = 0.10 (p = 0.339)	d = 0.00 (p = 1.000)
A_{to} (º)	Pre	18.7 ± 3.9	21.2 ± 3.8	19.0 ± 3.6	19.8 ± 3.8
	Post	21.1 ± 4.1	20.9 ± 3.3	18.1 ± 3.0	19.6 ± 2.2
	Cohen's d	d = 0.58 (p = 0.016)	d = -0.10 (p = 0.700)	d = -0.25 (p = 0.293)	d = -0.07 (p = 0.813)
A_{mkf} (º)	Pre	135.5 ± 8.0	137.9 ± 5.0	135.0 ± 6.4	139.9 ± 5.8
	Post	136.6 ± 6.0	135.4 ± 5.5	131.1 ± 7.7	132.6 ± 4.2
	Cohen's d	d = 0.16 (p = 0.589)	d = -0.48 (p = 0.120)	d = -0.54 (p = 0.002)	d = -1.18 (p = 0.004)
A_{i-td} (º)	Pre	60.4 ± 2.8	59.5 ± 2.5	59.2 ± 3.0	56.5 ± 3.0
	Post	57.4 ± 2.1	58.5 ± 2.7	57.1 ± 2.5	56.6 ± 2.4
	Cohen's d	d = -1.04 (p = 0.001)	d = -0.38 (p = 0.171)	d = -0.73 (p = 0.002)	d = 0.03 (p = 0.951)
A_{i-to} (º)	Pre	72.4 ± 3.6	74.2 ± 3.0	72.7 ± 3.1	76.3 ± 2.9
	Post	76.7 ± 3.6	75.9 ± 2.5	72.9 ± 2.6	74.2 ± 2.5
	Cohen's d	d = 1.03 (p < 0.001)	d = 0.59 (p = 0.031)	d = 0.05 (p = 0.864)	d = -0.73 (p = 0.051)

NOTE. Cohen's d = (Post – Pre)/SD pooled; Con - no feedback; Ve_BF - verbal feedback on key errors; Ve+Vi_BF - verbal and video feedback on key errors; Ve+Vi_100% - verbal and video feedback on all errors; D_{eff} - effective jump distance (in centimetres); VR_{to} - CG resultant velocity at the end of take-off (in meters per second); VX_{td} - CG horizontal velocity at the instant of touch-down (in meters per second); T_d - take-off duration (in milliseconds); A_{to} - take-off angle (in degrees); A_{mkf} - maximum knee flexion angle (in degrees); A_{i-td} - inclination angle at the instant of touch-down (in degrees); and A_{i-to} -inclination angle at the end of take-off (in degrees).

Velocity and temporal parameters

Training intervention did not produce any significant changes within or between groups in resultant velocity at take-off (VX_{td}) and take-off duration (T_d). However, horizontal velocity changed significantly in the Con (3.0 ± 5.2%, d = 0.27, p = 0.031) and Ve+Vi_BF (8.3 ± 9.2%, d = 0.62, p < 0.001) groups, but not in the Ve_BF (1.6 ± 8.2%, d = 0.12, p = 0.447) and the Ve+Vi_100% (2.1 ± 4.1%, d = 0.17, p = 0.094) groups. There were no significant changes between groups in horizontal velocity.

Spatial parameters

The control group demonstrated significant increase in take-off angle (15.7 ± 23.1%; d = 0.58, p = 0.016) and outperformed the Ve+Vi_BF (p = 0.007) group, which deteriorated at the end of intervention by -1.6 ± 20.6% (d = -0.25, p = 0.293). The Ve+Vi_BF and the Ve+Vi_100% groups significantly reduced the angle of maximal knee flexion by -2.9 ± 4.2% (d = -0.54, p = 0.002) and -5.0 ± 5.2% (d = -1.18, p = 0.004), respectively. The Con group was the only group that increased the angle of maximal knee flexion (d = 0.16, p = 0.589) and in this way the Con group significantly outperformed the Ve+Vi_BF (p = 0.025) group. Training intervention produced no between-group differences in the inclination angle at the beginning of the take-off. However, the Con and the Ve+Vi_BF groups reduced it significantly by -4.8 ± 4.8% (d = -1.04, p = 0.001) and by -3.4 ± 5.0% (d = -0.73, p = 0.002), while the other two groups did not (Ve_BF and Ve+Vi_100%).

8 weeks of practice with or without augmented feedback resulted in a significant change in inclination angle at the end of take-off within two groups and between three pairs of groups. The Con group increased inclination by 6.0 ± 4.3% (d = 1.03, p < 0.001) and the Ve_BF group increased it by 2.4 ± 4.3% (d = 0.59, p < 0.031). A non-significant increase in inclination was observed in the Ve+Vi_BF (d = 0.05, p = 0.864) and decrease in the Ve+Vi_100% (d = -0.73, p = 0.051) groups. The changes listed above resulted in a significant difference between the Con and the Ve+Vi_BF (p < 0.001) group, the Con and the Ve+Vi_100% (p = 0.002) group, and lastly, the Ve_BF group compared to the Ve+Vi_BF (p = 0.018) group.

Discussion

In this study, we examined the effects of varying augmented feedback on the long jump skill acquisition in elementary school children. Although all groups improved significantly in terms of the jump distance, our results show that the Ve+Vi_100% group was the only one that significantly outperformed all other groups, in this variable (Figure 1.A). The corresponding effect sizes in the control and the Ve_BF groups were small, whereas these effect sizes in the Ve+Vi_BF and the Ve+Vi_100% groups were medium (Table 3). This finding contradicts our hypothesis that reduced feedback is more beneficial to a long jump skill acquisition than the more frequent feedback (i.e., feedback provided after every jump during practice).

No changes within or between groups occurred in CG resultant velocity at the end of take-off (Figure 1.B). Given the jump distance improvement in all groups, we expected higher effect sizes than observed (Table 3). Studies on long jump kinematics proved that resultant velocity is highly related ($r = 0.56 – 0.61$) to the effective jump distance (Lees et al., 1994; Antekolović, 2007) and that considerable proportion of jump distance variance can be explained using resultant velocity. Relative within-group changes in resultant velocity in our study varied from 1.5% in the Con to maximal 4.7% change in the Ve+Vi_BF group. At the same time, the Ve+Vi_BF group increased their jumping distance by 15.8%. We can assume that there was a cumulative effect of resultant velocity and other parameters that lead to a significant improvement in jumping distance.

Approach speed, also highly related to jumping distance (Hay, 1993), in our study represented by CG horizontal velocity at the instant of touch-down, had shown a maximal increase of 8.3 ± 9.2% for the Ve+Vi_BF group, with medium effect size ($d = 0.62$, $p < 0.001$), while Panteli et al. (2013) reported small effect sizes for this variable. The control group also improved by 3.0 ± 5.2% (Figure 1.C) in their horizontal velocity, but the effect size was small ($d = 0.27$, $p = 0.031$). One possible way to explain this phenomenon is the fact that the control group practiced without feedback, while other groups focused on other details presented to them. Exercising without feedback consequently led to an increased approach speed because all groups received initial information before every single training session to run as fast as possible in their approach. Another possible explanation is that a linear relation between horizontal velocity and jumping distance in children also exists, but it is far weaker ($r = 0.29$), as reported by Panteli et al. (2013).

Take-off duration (Figure 1.D) shows no significant change within or between groups under the influence of intervention. This kinematic parameter can be subdivided into the compression phase (from the instant of touch-down of take-off leg to the instant of the maximal knee flexion) and extension phase (from the instant of maximal knee flexion to the instant of the take-off) (Graham-Smith & Lees, 2005). During the compression phase, the muscle and tendon complex stores energy produced by run-up and then releases it in the extension phase of the take-off. Most of the vertical take-off velocity is created via the release of stored elastic energy, and by a release of muscle chemical energy during the concentric contraction (Lees et al., 1994). However, the compression phase is also related to CG horizontal velocity loss, so this subphase of the take-off should be as short as possible. In other words, less knee flexion produces higher CG vertical velocity. Contrary to this fact, in our study, the Ve+Vi_BF and the Ve+Vi_100% were the groups that gained the most in jumping distance (12.4 ± 10.1%, $d = 0.53$, $p < 0.001$ and 15.8 ± 12.8%, $d = 0.61$, $p < 0.001$), but decreased the angle of maximal knee flexion to 131.1 ± 7.7° (Ve+Vi_BF) and 132.6 ± 4.2° (Ve+Vi_100%) at the end of the intervention. The calculated effect sizes in those groups were medium (Ve+Vi_BF; $d = -0.54$, $p = 0.002$) and large (Ve+Vi_100%; $d = -1.18$, $p = 0.004$), respectively. At the same time, the control group increased the angle of maximal knee flexion by 1.4 ± 6.5% ($d = 0.16$, $p = 0.589$), to 136.6 ± 6.0° at the end of the intervention (Figure 1.F).

Controversially, we expected a reverse trend across groups in maximal knee flexion, but children utilize augmented feedback differently than adults, as reported by Goh et al. (2012). Another reason may be the lack of lower extremity power in children to execute the proper take-off technique.

Take-off angle is another parameter where we detected a significant difference between the control and the Ve+Vi_BF group (15.7 ± 23.1% vs. -1.6 ± 20.6% change). Based on the information received at the beginning of every session (not feedback), the control group significantly increased their take-off angle compared to other groups, and the calculated effect size in that group was medium (d = 0.58, p = 0.016). The optimum take-off angle can be an estimated base on the specific properties of every jumper (Linthorne et al., 2005). Theoretically, a higher value of the take-off angle, in combination with a faster approach, should give better long jump performance.

A jumper must adjust his inclination angle at the beginning of the take-off compared to the inclination angle they utilize in their approach by leaning backward in order to plant their take-off foot in the front of CG. It is necessary to incline at the beginning of the take-off to neutralize the forward angular momentum (Hay, 1993) in order to maintain balance in the flight phase of the long jump. No between-group differences were produced by significant pre to post changes (Con and Ve+Vi_BF) in the inclination angle at the beginning of the take-off (Figure 1.G). The calculated pre-post change and effect size in the Ve+Vi_100% group was trivial in this variable (0.4 ± 7.3%, d = 0.03, p = 0.951) because they had optimal inclination before the intervention, compared to other groups (Table 3). On the other hand, the calculated effect sizes in other groups ranged from small in the Ve+Vi_100% group (d = 0.03, p = 0.951) to large (d = -1.04, p = 0.001) in the control group (Table 3). The values of the inclination angle at the beginning of the take-off (all groups, after intervention) reported in Table 3 are very similar to the values produced by elite jumpers (56.6 ± 3.7°), as reported by Antekolović (2007).

Our intervention produced three significant between-group differences in the inclination angle at the end of take-off (Table 1.H), also called the angle of attack (Béres et al., 2014). Approach velocity and the angle of attack are negatively correlated (Antekolović, 2007; Béres et al., 2014), meaning, the higher the approach velocity, the smaller the angle of attack. Based on the feedback received, only the Ve+Vi_100% group succeeded in decreasing the angle of attack while increasing horizontal velocity, although changes were not significant. Other groups had significantly increased the angle of attack (Table 3), the control group to the largest extent (6.0 ± 4.3%), followed by the Ve_BF (2.4 ± 4.3%) group, while the change in the Ve+Vi_BF (0.3 ± 5.0%) group was insignificant.

Even though the control group had the second-best horizontal velocity improvement and did increase the take-off angle substantially, their improvement in the jumping distance was the poorest compared to other groups. Moreover, the control group had a significantly lower improvement in jumping distance compared to the Ve+Vi_100%

group. On the other hand, the Ve+Vi_100% group achieved their improvement in the jumping distance throughout adjustment of the angle of attack and maximal knee flexion.

The primary limitation to the generalization of these results is the lack of random assignment of participants to treatment groups. Our main concern was to eliminate any interference of feedback given to participants from different groups. Because the experiment was conducted in a natural school setting, it was impossible to extract students from the existing class groups and create new ones. Therefore, we decided to keep the existing class groups and randomly assign them to one of the experimental or control treatments. Another limitation of the study is the lack of a kinematic analysis of the landing phase of the long jump. We assumed that most of the changes between groups will occur in the take-off phase. Based on the feedback received, it is possible that the Ve+Vi_100% group significantly improved the efficiency of the landing phase. Future studies should consider to include all phases of the long jump in the analysis.

Conclusion

Compared with previous similar studies that used BF as a method of reducing feedback in school-aged children (Ugrinowitsch et al., 2010; Sadowski et al., 2013), we did not find any benefits of reduced feedback in children. Moreover, we did not confirm the research of Giannousi and Kioumourtzoglou (2017) in which they concluded that a combination of verbal and visual feedback is more effective than the verbal alone.

Based on the results of the present study, we suggest that children benefit more from more frequent feedback, which is in line with earlier findings of Chiviacowsky et al. (2008), Sullivan et al. (2008) and Goh et al. (2012). They stated that more frequently given feedback in earlier stages of learning of novel motor tasks is more beneficial than reducing feedback beyond the critical point.

While it is not apparent where the critical point could be, one could make a mistake in determining the bandwidth. We focused on three key beginner jumping errors that covered two out of four phases of the jump (approach and take-off, but not flight and landing). In this way, we withheld other feedback, which may have helped children in the learning process. We suggest that future studies include different bandwidths into the experimental design so that the critical point of reducing the feedback could be established.

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Usvajanje tehnike skoka u dalj korištenjem povratnih informacija različitih vrsta i frekvencija

Sažetak

Cilj ovoga rada bio je ispitati utjecaj različitih količina i vrsta povratnih informacija (PI) u procesu usvajanja tehnike skoka u dalj kod učenika osnovne škole. Osamdeset i osam učenika i učenica, starosti 11 (±0,5) godina, bez prethodnoga iskustva u treningu skoka u dalj, raspodijeljeno je u jednu od četiriju skupina ispitanika koje su dobivale PI: (1) verbalno samo na ključne greške, (2) verbalno i vizualno samo na ključne greške, (3) verbalno i vizualno na sve greške ili (4) nisu primale PI. Duljina skoka i relevantni kinematički parametri skoka u dalj izmjereni su prije i nakon osmotjednog eksperimentalnoga tretmana. Rezultati istraživanja pokazali su kako je grupa koja je primala PI, na svaku grešku verbalnim i vizualnim putem najviše napredovala u smislu duljine skoka u dalj. Različite količine i vrste PI različito djelovale su na promatrane kinematičke parametre te nisu uočene konzistentne promjene između grupa. Zaključeno je kako djeca osnovnoškolske dobi prilikom usvajanja kompleksne motoričke vještine imaju više koristi od većih frekvencija PI (verbalnih i vizualnih na sve greške) u usporedbi s reduciranim PI prema vrsti (samo verbalne) ili frekvenciji (samo na ključne greške).

Ključne riječi: *kinematika; motoričko učenje; poznavanje izvedbe; reducirane povratne informacije.*

Uvod

Proces motoričkoga učenja izaziva promjene u unutrašnjim procesima koji određuju sposobnost čovjeka za izvedbu motoričkoga zadatka. Jedan od važnijih načina kojim učitelji mogu utjecati na proces motoričkoga učenja je davanje informacija o izvedenom motoričkom zadatku. Takav tip informacija zovemo vanjske PI (Schmidt i Wrisberg, 2004). Poznavanje rezultata i poznavanje izvedbe motoričkoga zadatka dva su podtipa vanjskih PI. PI vezane uz rezultat obično se daju odmah po završetku motoričkoga zadatka i najčešće se odnose na verbalne PI o stupnju zadovoljenja samog zadatka. PI vezane uz izvedbu daju se na sličan način kao i PI vezane uz rezultat, ali mogu sadržavati verbalne i vizualne informacije o izvedenim pokretima tijekom motoričkoga zadatka. Takve PI, koje nazivamo i kinematičke PI, odnose se na poziciju, brzinu ili ubrzanje određenih dijelova tijela, a mogu uključivati i informacije o rasporedu određenih dijelova tijela u odnosu na ostale dijelove tijela (Schmidt i Young, 1991). Ova vrsta PI često se koristi u praksi prilikom usvajanja kompleksnih motoričkih vještina. Kinematičke PI koriste se na nekoliko načina: kao verbalno–deskriptivne (PI o greški u izvedbi), kao verbalno-preskriptivne (PI o greški i načinu ispravljanja greške), pregledavanjem snimljenih izvedbi motoričkih zadataka, s ili bez kinematičke i/ili kinetičke analize pokreta, i zadnje, korištenjem biološke povratne sprege za analizu izvedenoga pokreta (Magill i Anderson, 2014). 100 % frekvencija PI predstavlja davanje PI nakon svakog pokušaja izvedbe motoričkoga zadatka, a ostale strategije davanja PI usmjerene su na njihovu redukciju.

Istraživanja na frekvencijama PI pokazala su kako se redukcijom PI može učinkovitije usvajati jednostavnije motoričke zadatke kao što su: pomicanje ruke u određeni položaj i proizvodnja određene količine sile mišićnom kontrakcijom (Lee i Carnahan, 1990; Winstein, Pohl i Lewthwaite, 1994; Park, Shea i Wright, 2000; Agethen i Krause, 2016) ili pritiskati gumbe prema unaprijed određenom rasporedu (Wulf, Lee i Schmidt, 1994; Badets i Blandin, 2010). Fokus nabrojenih istraživanja ograničava se na jednostavnije motoričke vještine ograničene na izvedbu u laboratorijskim uvjetima. Primjena zaključaka nabrojenih studija na kompleksnije motoričke vještine i situacijske uvjete u sportu nije u potpunosti moguća, odnosno, postavlja se pitanje generalizacije rezultata navedenih studija (Wulf i Shea, 2002). S druge strane, postoje istraživanja koja su potvrdila tezu kako reducirane PI imaju blagotvoran učinak na usvajanje kompleksnih motoričkih vještina kao što su izvođenje kratkih i preciznih udaraca palicom u golfu (Smith, Taylor i Withers, 1997), gađanje mete nogometnom loptom (Wulf, Mcconnel, Gärtner i Schwarz, 2002) ili pikado strelicom (Coca-Ugrinowitsch i sur., 2014).

U suprotnosti s gore navedenim istraživanjima, postoje dokazi kako uporaba visokih frekvencija PI prilikom usvajanja novih jednostavnih, ali i složenih motoričkih vještina predstavlja bolju strategiju motoričkoga učenja (Wulf, Shea i Matschiner, 1998; Fujii, Lulic i Chen, 2016), ali samo u fazi početnoga usvajanja. Učinak takve strategije u retenciji često nestane (Mononen, Viitasalo, Konttinen i Era, 2003), što je u skladu s tezom Schmidta i Wulfa (1997) prema kojoj visoke frekvencije PI, koje se daju tijekom vježbanja, narušavaju preciznost i stabilnost motoričkih programa u pozadini motoričke vještine. Sve dosad nabrojene studije povezane s frekvencijom PI koristile su mlade, ali odrasle ljude kao ispitanike. Rezultati takvih studija teško mogu biti primjenjivi kada su u pitanju djeca. Pojedina istraživanja provedena na djeci pokazuju kako reducirane PI mogu imati bolje učinke nego visoke frekvencije PI. Istraživanje provedeno na djeci prilikom usvajanja vještine ubacivanja nogometne lopte u igru rukama pokazalo je kako 33 % relativne frekvencije PI u vidu poznavanja izvedbe proizvode bolje učinke nego 100 % relativna frekvencija PI (Weeks i Kordus, 1998). Sličan zaključak daje i nešto novija studija koja utvrđuje preciznost gađanja mete (Zamani i Zarghami, 2015).

Međutim, Goh, Kantak i Sullivan (2012) tvrde kako djeca, u usporedbi s odraslima, tijekom usvajanja motoričke vještine na PI reagiraju drugačije. Oni u svojem istraživanju koriste strategiju postupnoga smanjivanja PI kroz eksperiment i zaključuju kako djeca mogu učiti nove obrasce kretanja učinkovito kao i odrasli, jedino ako dobivaju PI nakon svakog pokušaja prilikom vježbanja. Takav zaključak je u skladu s tvrdnjama kako djeci više koriste visoke frekvencije PI, u usporedbi s reduciranim PI (Chiviacowsky, Wulf, de Medeiros, Kaefer i Wally, 2008). Uz to, Sullivan, Kantak i Burtner (2008) sugeriraju kako bi PI kod djece trebalo smanjivati postupno kroz proces usvajanja vještine jer redukcija PI preko kritične točke može imati nepovoljne učinke na motoričku izvedbu i učenje. U tom smislu, posebno su zanimljive studije koje koriste princip ključnih grešaka prilikom učenja i usvajanja motoričkih vještina u situacijskom okruženju. Takve studije pokazuju kako korištenje nešto širih popisa ključnih grešaka predstavlja dobru strategiju redukcije PI (Ugrinowitsch, Fonseca, Carvalho, Profeta i Benda, 2010; Sadowski, Mastalerz i Niznikowski, 2013). Prilikom primjene takve strategije subjekt dobiva PI isključivo tada kada njegova izvedba izlazi izvan okvira zadane tolerancije (Schmidt i Wrisberg, 2004). Subjekt koji dobiva PI o greškama koje je učinio tijekom izvedbe motoričkoga zadataka, mora biti svjestan i činjenice kako izvedba zadatka nakon kojeg ne dobiva PI, znači dobru izvedbu. Takva je strategija učinkovita jer se u početnim fazama motoričkoga učenja koriste visoke frekvencije PI, a kasnije se one reduciraju, što je logična posljedica redukcije PI prema principu ključnih grešaka (Lee, Swinnen i Serrien, 1994).

Kombinacija verbalnih i vizualnih PI poznavanja izvedbe je metoda koja se često koristi u praksi. Giannousi i Kioumourtzoglou (2017) u svojem istraživanju na plivačima početnicima pokazuju kako upravo takva kombinacija može biti učinkovitija u odnosu na metodu u kojoj se koriste samo verbalne PI, a u kombinaciji s redukcijom PI po principu ključnih grešaka može proizvesti najbolje rezultate (Niznikowski, Nogal, Biegajlo, Wisniowski i Niznikowska, 2016).

U ovom istraživanju postavili smo hipotezu kako reducirane PI, prema principu ključnih grešaka, u vidu poznavanja izvedbe kompleksnoga motoričkog zadatka kod djece, mogu proizvesti bolje učinke u usporedbi s visokim frekvencijama PI te da je kombinacija verbalnih i vizualnih PI učinkovitija od PI prezentiranih samo verbalnim putem. Svrha ovoga eksperimenta bila je istražiti utjecaj različitih vrsta i frekvencija PI na proces početnoga usvajanja tehnike skoka u dalj.

Metode

Ispitanici

Osamdeset i osam dječaka i djevojčica, učenika osnovne škole, bez prethodnoga iskustva u treningu skoka u dalj pristupilo je eksperimentu. U finalnu obradu podataka ušli su najbolji skokovi sedamdeset i pet ispitanika. Trinaest ispitanika isključeno je zbog manjeg broja odrađenih treninga (ispod 80 %), nepojavljivanja na danu završnoga mjerenja ili su njihovi rezultati označeni kao netipična vrijednost (upotrebom interkvartilnoga raspona). Istraživanje je odobrilo Povjerenstvo za znanstveni rad i etiku Kineziološkog fakulteta u Zagrebu. Suglasnost o sudjelovanju u istraživanju potpisali su roditelji ispitane djece. Postojeći razredni odjeli korišteni su kao grupe ispitanika. Slučajnim odabirom dodijeljen im je jedan od programa vježbanja tehnike skoka u dalj s različitim vrstama i količinama PI: reducirane verbalne PI na ključne greške u izvedbi (Ve_BF, n = 19), reducirane verbalne i vizualne PI na ključne greške (Ve+Vi_BF, n = 24), verbalne i vizualne PI na sve greške (Ve+Vi_100 %, n = 14) i grupa bez PI predstavljala je kontrolnu grupu (Con, n = 18). Kako je istraživanje provedeno u normalnom školskom okruženju (odnosno na satu TZK), nije korišten slučajni odabir ispitanika u grupe zbog potencijalne interakcije između sudionika. Na primjer, pripadnici kontrolne skupine mogli bi čuti verbalne povratne informacije namijenjene samo eksperimentalnim grupama.

Varijable

Eksperimentalni uvjeti treninga predstavljali su nezavisnu varijablu gdje je količina i vrsta PI varirala prema ranije navedenom opisu grupa: verbalne PI na ključne greške (Ve_BF), verbalne i vizualne PI na ključne greške (Ve+Vi_BF), verbalne i vizualne PI na sve greške (Ve+Vi_100 %) i bez PI (Con). Tehnika skoka u dalj predstavljala je zavisnu varijablu koja je opisana efektivnom duljinom skoka u dalj i sljedećim kinematičkim parametrima: horizontalnom brzinom težišta tijela (TT) na početku odraza (VX_{td}), rezultantnom brzinom TT na kraju odraza (VR_{to}), trajanjem odraza (T_d), kutom uzleta (A_{to}), kutom amortizacije odraza (A_{mkf}), kutom tijela na početku odraza (A_{i-td}) i kutom tijela na kraju odraza (A_{i-to}). Kako je odraz centralni dio skoka u dalj, kinematički parametri koji najbolje opisuju odraz odabrani su jer skakač mora, da bi proizveo vertikalni impuls sile, najprije proizvesti impuls sile u smjeru podloge (Alexander, 1990).

Mjerni postupci

Ispitanici su bili podvrgnuti standardiziranom inicijalnom i finalnom mjerenju duljine skoka u dalj u atletskoj dvorani. Svaki ispitanik izvršio je 4 skoka u dalj iz zaleta ne kraćeg od 15 i ne dužeg od 20 metara. Odraz je bio dozvoljen jednom nogom, a doskok se vršio u pješčanik na obje noge. Za određivanje duljine skoka ispred doskočišta iscrtana je zona odraza veličine 1 x 1 metar. Zona odraza je bila posuta tankim slojem vapna kako bi se precizno odredilo mjesto odraza ispitanika (linija palca odrazne noge). Točka mjesta odraza proširena je u liniju okomito na zalet kako bi se izmjerila udaljenost od mjesta odraza do najbliže točke ulegnuća pijeska u doskočištu (prema pravilima Međunarodne atletske federacije). Svi skokovi bili su izmjereni čeličnim metrom i snimani s dvije Sony HDR-HC9E kamere (50 sličica u sekundi) i jednom Casio EX-ZR100 digitalnom kamerom (240 sličica u sekundi). Digitalna štoperica s ekranom dijagonale 5 inča bila je postavljena na desnu stranu zone odraza kako bi se omogućila kasnija sinkronizacija videozapisa za kinematičku analizu skokova. Sony kamere bile su postavljene na lijevoj strani, udaljene 5 metara od zone odraza i međusobno pod kutom od otprilike 90 stupnjeva. Casio kamera bila je postavljena između njih i snimala je samo stopalo odrazne noge ispitanika. 3D kinematička analiza izvedena je na najboljem skoku iz inicijalnoga i kasnije finalnoga mjerenja. Kinematička analiza izvedena je prema APAS (Ariel Performance Analysis System) standardima. Jedini parametar dobiven snimkom Casio kamere i obradom u Kinovea videoalatu za analizu sportske izvedbe bilo je trajanje odraza (T_d). Sličica u kojoj je bio jasno vidljiv prvi kontakt s podlogom označena je početkom odraza, a posljednji jasno vidljivi kontakt označen je krajem odraza.

Eksperimentalni tretman

Nakon inicijalnoga testiranja, svi su ispitanici pristupili treningu skoka u dalj. Eksperimentalni tretman trajao je 8 tjedana, 2 treninga tjedno u sklopu nastave TZK-a, ukupno 16 sati treninga. Na početku svakog sata ispitanici su dobivali jednake uvodne informacije putem videodemonstracije tehnike skoka u dalj popraćene standardiziranim verbalnim uputama. Nakon toga ispitanici su uvježbavali tehniku skoka u dalj. Zadatak je bio izvesti 10 skokova po satu uz verbalne ili verbalne i vizualne PI na sve ili samo na ključne greške, koje su davali nastavnici TZK-a s dovoljnim iskustvom u atletici da mogu prepoznati greške i izabrati standardiziranu uputu za ispravljanje (Tablica 1) Kontrolna skupina nije dobivala PI tijekom cijeloga tretmana. Prva 4 sata vježbanja koristio se zalet od 6 koraka. Zalet se je produživao svaka 4 sata za 2 koraka, na taj način zadnja 4 sata ispitanici su koristili zalet od 12 koraka prilikom vježbanja tehnike skoka u dalj. Progresija dužine zaleta ispitanicima je omogućavala da najprije svladavaju tehniku pri manjim brzinama, uz veću kontrolu pokreta.

Prije samog početka eksperimenta, autori ove studije sastavili su popis od 14 mogućih početničkih grešaka u tehnici skoka u dalj. Atletski treneri eksperti (n = 21) ocijenili su svaku grešku s popisa putem upitnika konstruiranoga za potrebe ovoga istraživanja. Koristila se Likertova sedmostupanjska ljestvica: 1. stupanj označavao je nevažnu grešku, a 7. stupanj ključnu grešku u tehnici skoka u dalj kod djece–početnika. Prilikom vježbanja, 3 greške s najvišim ocjenama korištene su kao ključne u grupama s reduciranim PI, svih 14 korišteno je u grupi s 100 % PI (do 3 greške po skoku). Autori istraživanja definirali su i verbalne upute za ispravljanje pojedinih grešaka (Tablica 1). Grupe Ve+Vi_BF i Ve+Vi_100 %, uz verbalne primale i su video PI izvedbe tehnike svojih skokova, na ekranu računala, odmah nakon izvedenoga skoka.

Tablica 1.

Statističke analize

Shapiro–Wilk testom analiziran je normalitet distribucija i homogenost varijance rezultata inicijalnoga i finalnoga mjerenja svih varijabli. Po verifikaciji normaliteta i homogenosti, a prije korištenja multivarijatne analize varijance (MANOVA), serijom korelacijskih analiza testirana je pretpostavka o nepostojanju multikolinearnosti između svih zavisnih varijabli. Rezultati su pokazali umjerenu međusobnu povezanost zavisnih varijabli (r = 0,11 – 0,87). Dodatno, vrijednost Boxova M-testa od 162,28 u kombinaciji sa značajnošću od p = 0,105 pokazuje kako su matrice kovarijanci između grupa jednake. Po verifikaciji svih nužnih pretpostavki, korištena je MANOVA za utvrđivanje razlika između grupa u inicijalnom mjerenju. Kako su utvrđene razlike između grupa u inicijalnom mjerenju, za utvrđivanje utjecaja eksperimentalnog tretmana na kinematičke varijable korištena je analiza kovarijance (ANCOVA) s rezultatima inicijalnoga testiranja kao kovarijatom. Ako je ANCOVA-om utvrđena statistički značajna razlika između grupa, Bonferroni post-hoc testom utvrđivao se izvor razlika između grupa. Prije upotrebe ANOVA-i, a kako vi uz sve ostale uvjete testirali i uvjet homogenosti regresijskih pravaca, korišteni su dijagrami raspršenosti.

Za uvid u veličinu učinka unutar grupa izračunat je Cohenov d, vrijednosti veličine učinka manje od 0,19 interpretirane su kao trivijalne, 0,20 do 0,49 kao male, 0,50 do 0,79 kao srednje, odnosno veće od 0,80 kao velike. Statistička značajnost veličine učinka utvrđivala se Studentovim t-testom za zavisne uzorke. Razina statističke značajnosti bila je postavljena na p < 0,05. Svi podatci prikazani su kao aritmetička sredina ± SD ili relativna promjena rezultata ± SD. IBM SPSS Statistics za Windows, verzija 20,0. Armonk, NY: IBM Corp. korištena je za sve statističke analize.

Rezultati

MANOVA je pokazala da na rezultatima inicijalnoga mjerenja postoje statistički značajne razlike između grupa (p < 0,001). Konkretno, razlike su opažene u sljedećim kinematičkim parametrima: horizontalnoj brzini TT na početku odraza (VX_{td}, p = 0,001), trajanju odraza (T_d, p = 0,006), kutu tijela na početku odraza ($A_{i\text{-}td}$, p = 0,003) i kutu tijela na kraju odraza ($A_{i\text{-}to}$, p = 0,004).

Statistički značajne razlike između grupa nakon eksperimentalnoga tretmana, utvrđene serijom ANCOVA, nađene su kod sljedećih varijabli (Tablica 2): efektivnoj duljini skoka (D_{eff}, p = 0,004), kutu uzleta (A_{to},p = 0,011), kutu amortizacije (A_{mkf}, p = 0,012) i kutu tijela na kraju odraza ($A_{i\text{-}to}$, p < 0,001). Statistički značajne razlike nisu pronađene kod varijabli: rezultantna brzina TT na kraju odraza (VR_{to}, p = 0,349), horizontalna brzina TT na početku odraza (VX_{td}, p = 0,145) trajanje odraza (T_d, p = 0,253) i kutu tijela na početku odraza ($A_{i\text{-}td}$, p = 0,207).

Tablica 2.

Duljina skoka

Sve grupe postigle su statistički značajan napredak u duljini skoka u dalj po završetku treninga. Konkretno, kontrolna skupina (Con) je napredovala 6,7 ± 12,4 % (d = 0,28, p = 0.041), 8,7 ± 11,3 % Ve_BF grupa (d = 0,39, p = 0,003), 12,4 ± 10,1 % Ve+Vi_BF grupa (d = 0,53, p < 0,001) i 15,8 ± 12,8 % Ve+Vi_100 % grupa (d = 0,61, p < 0,001). Ve+Vi_100 % grupa je statistički značajno napredovala u duljini skoka u odnosu na ostale grupe (Tablica 2).

Slika 1.

Tablica 3.

Parametri brzine i vremena

Eksperimentalni tretman nije proizveo statistički značajnu promjenu unutar ili između grupa u rezultantnoj brzini (VR_{to}), kao ni u varijabli trajanje odraza (T_d). Međutim, značajno povećanje horizontalne brzine TT vidljivo je kod Con grupe (3,0 ± 5,2 %, d = 0,27, p = 0,031) i Ve+Vi_BF grupe (8,3 ± 9,2 %, d = 0,62, p < 0,001), ali ne i kod Ve_BF (1,6 ± 8,2 %, d = 0,12, p = 0,447) i Ve+Vi_100 % (2,1 ± 4,1 %, d = 0,17, p = 0,094). Razlike između grupa u horizontalnoj brzini zaleta nisu statistički značajne.

Prostorni parametri

Kontrolna grupa je značajno povećala kut uzleta (15,7 ± 23,1 %; d = 0,58, p = 0,016) što je proizvelo statistički značajnu razliku u odnosu na Ve+Vi_BF grupu (p = 0,007) koja je smanjila kut uzleta nakon 8 tjedana treninga za -1,6 ± 20,6 % (d = -0,25, p = 0,293). Grupe Ve+Vi_BF i Ve+Vi_100 % značajno su smanjile kut amortizacije u koljenu odrazne noge za -2,9 ± 4,2 % (d = -0,54, p = 0,002) , odnosno za -5,0 ± 5,2 % (d = -1,18, p = 0,004). Kontrolna grupa jedino je povećala kut amortizacije (d = 0,16, p = 0,589) što predstavlja statistički značajno povećanje u odnosu na Ve+Vi_100 % (p = 0,025). Eksperimentalni tretman nije proizveo značajne razlike između grupa u varijabli kut tijela na početku odraza ($A_{i\text{-}td}$). Međutim, grupe Con i Ve+Vi_BF su ga smanjile značajno, i to za -4,8 ± 4,8 % (d = -1,04, p = 0,001), odnosno za -3,4 ± 5,0 % (d = -0,73, p = 0,002), bez promjena u ostale dvije grupe (Ve_BF i Ve+Vi_BF).

Osam tjedana treninga sa ili bez PI rezultiralo je značajnim razlikama unutar dvije grupe i između tri para grupa u varijabli kut tijela na kraju odraza ($A_{i\text{-}to}$). Kontrolna grupa povećala je kut za 6,0 ± 4,3 % (d = 1,03, p < 0,001), a Ve_BF grupa za 2,4 ± 4,3 % (d = 0,59, p < 0,031). Promjene u vrijednostima kuta tijela na kraju odraza bez statistike značajnosti uočene su kod Ve+Vi_BF grupe (d = 0,05, p = 0,864) i Ve+Vi_100 % grupe (d = -0,73, p = 0,051). Nabrojene promjene rezultirale su značajnim razlikama između kontrolne i Ve+Vi_BF grupe (p < 0,001), kontrolne i Ve+Vi_100 % grupe (p = 0,001), i zadnje, Ve_BF i Ve+Vi_BF grupe (p = 0,018).

Rasprava

U ovom istraživanju ispitali smo učinke različitih vrsta i količina PI na proces usvajanja tehnike skoka u dalj kod djece osnovnoškolske dobi. Iako su sve grupe statistički značajno povećale duljinu skoka u dalj, rezultati statističke analize pokazali su kako je Ve+Vi_100 % grupa postigla statistički značajno veći napredak u odnosu na sve ostale grupe (Slika 1 a). Analogno tome, veličina učinka u kontrolnoj i Ve_BF grupi bila je mala, dok je veličina učinka u Ve+Vi_BF i Ve+Vi_100 % grupi bila srednja (Tablica 3). Takvi rezultati u suprotnosti su s postavljenom hipotezom da će reducirane PI postići bolje učinke pri svladavanju tehnike skoka u dalj u odnosu na frekventnije PI, odnosno PI nakon svakog skoka tijekom treninga.

U varijabli rezultantna brzina TT na kraju odraza (VR_{to}) nisu uočene značajnije razlike unutar ili između grupa (Slika 1 b). Zbog poboljšanja u duljini skoka, očekivali smo veće vrijednosti veličine učinka od izračunatih (Tablica 3). Kinematička istraživanja skoka u dalj dokazala su kako je efektivna duljina skoka visoko uvjetovana rezultantnom brzinom (r = 0,56 – 0,61), odnosno da se značajna količina varijance efektivne duljine skoka može objasniti pomoću rezultantne brzine (Lees, Graham-Smith i Fowler, 1994; Antekolović, 2007). Relativne promjene rezultantne brzine unutar grupe u ovom istraživanju iznosile su od 1,5 % u kontrolnoj grupi do maksimalnih 4,7 % u Ve+Vi_BF grupi. Istovremeno, Ve+Vi_BF grupa povećala je duljinu skoka za 15,8 %. Ovdje možemo pretpostaviti da je kumulativni učinak rezultantne brzine i drugih kinematičkih parametara doveo do takvih, statistički značajnih promjena u efektivnoj duljini skoka.

Brzina zaleta, također vrlo visoko povezana s duljinom skoka (Hay, 1993), u ovom istraživanju zastupljena kroz varijablu horizontalne brzine TT na početku odraza, bilježi maksimalno povećanja od 8,3 ± 9,2 % u Ve+Vi_BF grupi, sa srednjom veličinom učinka (d = 0,62, p < 0,001), dok su Panteli, Tsolakis, Efthimiou i Smirniotou (2013) izvijestili o maloj veličini učinka. Kontrolna grupa također je napredovala u horizontalnoj brzini TT na početku odraza (3,0 ± 5,2 %), ali je veličina učinka bila mala (d = 0,27, p = 0,031) (Slika 1 c). Fenomen poboljšanja brzine zaleta u kontrolnoj grupi moguće je objasniti činjenicom kako su ispitanici unutar te grupe vježbali bez PI te su mogli pažnju usmjeriti dominantno na zalet. U isto vrijeme ispitanici iz ostalih grupa morali su fokus pažnje usmjeravati na ostale detalje koji su im bili prezentirani putem PI. Uvježbavanje bez PI dovelo je do povećanja brzine zaleta jer su sve grupe, uključujući i kontrolnu, na početku svakog treninga dobivale početne upute koje su uključivale i uputu s informacijom da zalet mora biti istrčan što je moguće brže. Drugo moguće objašnjenje ovoga fenomena je egzistencija linearne povezanosti između horizontalne brzine TT i duljine skoka kod djece, ali je slaba (r = 0,29) (Panteli i sur., 2013).

Eksperimentalni tretman nije utjecao na pojavu statistički značajnih razlika unutar ili između grupa u varijabli trajanje odraza (Slika 1 d). Ovaj kinematički parametar prema Graham-Smith i Leesu (2005) dijelimo u dvije podfaze: kompresijsku (od početka odraza do faze amortizacije u koljenu odrazne noge) i ekstenzijsku (od faze amortizacije do kraja odraza). Tijekom kompresijske podfaze, mišićno–tetivni kompleks upija energiju proizvedenu zaletom te je otpušta u ekstenzijskoj podfazi faze odraza. Većina vertikalne brzine TT u fazi odraza producira se otpuštanjem elastične energije, ali i kemijske energije proizvedene koncentričnom kontrakcijom mišića (Lees i sur., 1994). S druge strane, u podfazi kompresije gubi se dio horizontalne brzine TT, tako da bi ova podfaza trebala biti što kraća. U tom smislu, optimalno je da kut amortizacije koljena odrazne noge (A_{mkf}) bude što veći. Suprotno toj činjenici, u našem istraživanju, Ve+Vi_BF i Ve+Vi_100 % grupe ostvarile su najveći napredak u duljini skoka u dalj (12,4 ± 10,1 %, d = 0,53, p < 0,001 i 15,8 ± 12,8 %, d = 0,61, p < 0,001), ali su smanjile kut amortizacije na 131,1 ± 7,7° (Ve+Vi_BF) i 132,6 ± 4,2° (Ve+Vi_100 %) u finalnom testiranju. Izračunata vrijednost veličine učinka u tim grupama je bila srednja (Ve+Vi_BF; d = -0,54, p = 0,002), odnosno velika (Ve+Vi_100 %; d = -1,18, p = 0,004). Istovremeno, kontrolna grupa je povećala kut amortizacije za 1,4 ± 6,5 % (d = 0,16, p = 0,589) na 136,6 ± 6,0° (Slika 1 f). Suprotno očekivanjima, rezultati kinematičke analize pokazali su obrnuti trend relativnih razlika između grupa kod kuta amortizacije. Objašnjenje za pojavu ovakvih rezultata može biti činjenica kako djeca PI koriste drugačije nego odrasli (Goh i sur., 2012), ali i činjenica kako djeca nemaju dovoljno razvijen mišićno–tetivni kompleks da bi mogla izvesti korektan odraz u skoku u dalj.

Još jedan parametar u kojem smo detektirali značajnu razliku između kontrolne (15,7 ± 23,1 %) i Ve+Vi_BF grupe (-1,6 ± 20,6 %) je kut uzleta. Koristeći informacije dobivene na početku svakog treninga (bez PI), kontrolna grupa značajno je povećala kut uzleta u odnosu na ostale grupe, a izračunata veličina učinka za tu grupu bila je srednja (d = 0,58, p = 0,016). Optimalne vrijednosti kuta uzleta mogu se jedino procjenjivati, i to pojedinačno, za svakog skakača posebno, temeljem specifičnih karakteristika skakača (Linthorne, Guzman i Bridgett, 2005). U teoriji bi veća vrijednost kuta uzleta trebala producirati, u kombinaciji s brzim zaletom, veće vrijednosti duljine skoka u dalj.

Skakač mora prilagoditi kut tijela na početku odraza u odnosu na kut tijela koji koristi tijekom zaleta, tako da se nagne malo unatrag i omogući postavljanje stopala odrazne noge ispred TT. Takva prilagodba kuta tijela potrebna je i zbog neutralizacije zakretnoga momenta oko vlastite transverzalne osi (Hay, 1993), a sve kako bi se uspjela održati ravnoteža tijela tijekom faze leta. Iako su ispitanici iz kontrolne i Ve+Vi_BF značajno reducirali kut tijela na početku odraza, takve razlike unutar grupa nisu dovele do razlika između grupa (Slika 1 g). Izračunata relativna promjena za Ve+Vi_100 % grupu, kao i veličina učinka u kutu tijela na početku odraza je bila trivijalna (0,4 ± 7,3 %, d = 0,03, p = 0,951), iz razloga što su ispitanici unutar te grupe imali optimalni kut tijela već u inicijalnom mjerenju (Tablica 3). S druge strane, izračunata veličina učinka u ostalim grupama kretala se u rasponu od male u Ve+Vi_100 % grupi (d = 0,03, p = 0,951) do velike (d = -1,04, p = 0,001) u kontrolnoj grupi (Tablica 3). Vrijednosti kuta tijela na početku odraza iz Tablice 3 (sve grupe, finalno mjerenje) vrlo su slične onima koje postižu elitni skakači u dalj (56,6 ± 3,7°), prema Antekoloviću (2007).

Postignute su tri statistički značajne razlike između grupa kod varijable kut tijela na kraju odraza pod utjecajem eksperimentalnoga tretmana (Tablica 1 h). Kut tijela na kraju odraza, nazvan i napadnim kutom (Béres, Csende, Lees i Tihanyi, 2014) i brzina zaleta negativno su korelirani (Antekolović, 2007; Béres i sur., 2014). Povećanjem brzine zaleta smanjuje se napadni kut. Koristeći PI, jedino je Ve+Vi_100 % grupa uspjela, uz povećanje horizontalne brzine TT, smanjiti napadni kut, ali bez statističke značajnosti. Ostale grupe povećale su napadni kut (Tablica 3), kontrolna grupa značajno (6,0 ± 4,3 %), zatim Ve_BF značajno (2,4 ± 4,3 %) i na kraju, Ve+Vi_BF (0,3 ± 5,0%), bez statističke značajnosti.

Iako je kontrolna grupa imala drugo najbolje poboljšanje horizontalne brzine TT i značajno je povećala kut uzleta, poboljšanje u duljini skoka bilo je najmanje u usporedbi s ostalim grupama. Ve+Vi_100 % grupa je svoj napredak u duljini skoka postigla korekcijom napadnoga kuta i smanjivanjem kuta amortizacije te istovremeno postigla statistički značajno bolji napredak u duljini skoka u usporedbi s kontrolnom grupom.

Primarno ograničenje ovoga istraživanja svodi se na nedostatak slučajnoga odabira ispitanika u grupe. Eliminacija interferencije PI upućenih ispitanicima iz različitih grupa bio je jedan od glavnih zadataka pri izradi nacrta istraživanja. Kako se ovo istraživanje provodilo u normalnom školskom okruženju, nije bilo moguće izdvajati učenike iz postojećih grupa (razrednih odjeljenja) kako bi se stvorile nove grupe za potrebe istraživanja. Umjesto toga, postojeći razredni odjeli tretirani su kao grupe kojima je slučajnim odabirom dodijeljen jedan od eksperimentalnih ili kontrolni tretman. Dodatno ograničenje istraživanja je nedostatak kinematičke analize cijele tehnike skoka u dalj, odnosno njezinog doskoka. Pretpostavljeno je da će se najveći dio promjena uzrokovanih tretmanom dogoditi u fazi odraza. Međutim, s obzirom na PI koje su dobivali, moguće je da su ispitanici iz Ve+Vi_100 % grupe napredovali upravo u izvedbi doskoka. Iako je faza odraza njezin najvažniji dio, buduća istraživanja morala bi biti usmjerena na cijelu tehniku skoka u dalj.

Zaključak

Usporedbom s prijašnjim istraživanjima, koja su pri redukciji PI kod djece koristila princip ključnih grešaka (Ugrinowitsch i sur., 2010; Sadowski i sur., 2013), rezultati našega istraživanja nisu pokazali kako djeci redukcija PI koristi. Uz to, nismo uspjeli jasno potvrditi rezultate istraživanja Giannousia i Kioumourtzogloua (2017) u kojem navode kako je kombinacija verbalnih i vizualnih PI učinkovitija u usporedbi sa samo verbalnim.

Osnovom rezultata ovoga istraživanja zaključujemo kako djeca bolje napreduju u uvjetima učestalijih PI, što je u skladu sa zaključcima ranijih istraživanja (Chiviacowsky i sur., 2008; Sullivan i sur., 2008; i Goh i sur., 2012). Zaključak je tih istraživanja kako su učestalije PI korisnije u ranijim fazama svladavanja nove motoričke vještine u usporedbi s reduciranim PI, posebice ako se one reduciraju preko kritične točke.

Kako još uvijek nije jasno određena kritična točka preko koje se redukcija ne bi smjela vršiti, moguća je greška prilikom utvrđivanja ključnih grešaka. U ovom istraživanju fokusirali smo se na tri ključne početničke greške koje su se odnosile na dvije od četiriju faza skoka u dalj (zalet i odraz, ali ne let i doskok). Na taj način nismo ispravljali greške koje su djeci otežavale svladavanje tehnike skoka u dalj. Buduća slična istraživanja trebala bi u svoje nacrte uključiti različite količine ključnih pogrešaka kako bi se kritična točka redukcije PI mogla preciznije odrediti.