MOTOR LEARNING OF GROSS-MOTOR SKILLS UNDER VARIABLE PRACTICE CONDITIONS

Anita Haudum, Jürgen Birklbauer, Kröll Josef, Erich Müller
University of Salzburg, Salzburg, Austria
Christian Doppler Laboratory "Biomechanics in Skiing", Salzburg, Austria

ABSTRACT

Research background and hypothesis. For both the athlete and the coach, the purpose and goal of training is the same: to enhance performance.

Research aim. This study investigated the effect of differential learning on basketball free throw and volleyball strike.

Research methods. In the basketball experiment, in pre-, post- and retention test design, the free throw performance was measured (number of successful shots). Aiming to investigate transfer performance, jump shots were tested. In the volleyball experiment, movement variability during the strike was further increased by the application of an elastic constraint. The second intervention and quasi-control group trained under constant practice conditions. Ball velocity and accuracy were analysed with a constant and a variable test.

Research results. No significant differences were observed for either the free throw ($p > 0.05$) or the transfer performance ($p > 0.05$). However, a positive trend for the variable group was observed in the transfer situation. For the strike in volleyball, the differential learning group had a significant advantage with respect to velocity in a variable test situation ($p < 0.05$) whereas in the constant situation ($p > 0.05$) and measurements for accuracy ($p > 0.05$) it did not reveal similar results.

Discussion and conclusions. In both experiments, the set variability leads to benefits in variable (transfer) situations. However, as a practical consequence, especially for constant situations, certain moderator variables such as training age or background in other sports or activities must be kept in mind to adjust the amount of external or intervention-induced variability.

Keywords: differential learning, variability, adaptability, ball sports.

INTRODUCTION

For both the athlete and the coach, the purpose and goal of training is the same: to enhance performance. In human movement science and motor learning, various (theoretical) approaches and concepts that incorporate different forms of variable practice (e. g., Schema theory or differential learning) and task arrangements (i. e., constant, blocked variable or random) have been developed and investigated (Brady, 2004; Schöllhorn et al., 2009 a). In recent years, the integration of other (physiological and non-physiological) approaches – all focusing on variability – such as synergetics or dynamic system approaches, stochastic resonance, neurobiology, as well as artificial neural network simulations also emphasized the important role of variability in motor development and learning (e. g., Button et al., 2003; Schöllhorn et al., 2009 a, b). Consequently, the ambition to increase performance and to form an adaptable and flexible athlete has increasingly drawn attention to the advantage of variable training.

In addition to the abovementioned approaches, one approach that integrates the ideas of Russian neurophysiologist and movement pioneer Nikolai Bernstein (1967) is the differential learning approach by W. Schöllhorn et al. (2009 a). In differential learning, the athlete should explore and discover the individual optimum through self-organizing processes following enhanced fluctuations. These fluctuations, due to optimal perturbations within the organism, provoked by a noisy training environment, lead to movements seen as deviations from the task to-be-learned. The different executions should guide the learner towards his / her most effective movement co-ordination pattern. When the athlete has to adapt to force, the choice and order of exercises should be arranged in a way that no adaptation process would resemble an other one. Research showed similar, if not better performances than training methods typical for their sports, as well as constant practice or methodological rows (e. g. Schönherr, Schöllhorn, 2003; Birklbauer et al., 2006; Spratte et al., 2007).

To further test the idea of differential learning, we conducted two studies in complex sports on two different levels of play. In a study on the basketball free throw, we compared differential learning to standard training at different skill levels (13-year- to 16-year-olds). Our second experiment examined the volleyball strike. Participants were elite volleyball players and, as it is assumed that the strike technique is already matured on this level of play, movement variability within the movement task was further provided by using a special training device with elastic cords.

RESEARCH METHODS

Experiment 1. Fifty three youth basketball players (n = 52 males and 1 female; junior and under-16 basketball players; mean age: 14.3 ± 0.9 years, mean training age: 4.8 ± 1.3 years; top national youth level) practiced the free throw. Players were assigned either to one of the two intervention groups or a control group (CG) in a quasi-random manner based on their pre-test performance (successful and missed shot ratio). Each group consisted of 17 players whereby the number of players with respect to the skill level was counterbalanced across all groups.

Research Design. Intervention group 1 (IG1-BB) trained according to the differential learning approach whereas intervention group 2 (IG2-BB) practiced according to standard, constant free throw training. Participants completed 15 sessions and performed 50 free throws each session (without augmented feedback) over a period of 7.5 weeks (additional to the regular training). Pre-, post- and retention tests were done to measure free throw performance. In addition to counting the successful and missed free throws for a total of 20 test shots, all shots were rewarded according to a special point system (following D. Memmert (2006)): zero points for a missed shot; one point for a missed shot that touches the rim just once; two points for a missed shot that touches the rim more than once; four points for a successful shot that touches the rim; and five points for a successful "nothing but net" shot. The calculated sum was another parameter to estimate performance. On post- and retention test time points, transfer tests (TT) were done in which 20 jump shots with three dribbling prior to the jump were executed from a shooting position that was 45° right from the basket / board just behind the paint. Alike, the hit shots were counted and were rewarded according to the point system.

For the differential group, each session focused on a different aspect of the throw movement (e. g., knee angle, release point, wrist motion). Variations included movement errors and deviations, respectively, of the goal movement. Examples would be 1) shooting with the knees remaining flexed; 2) shooting with extreme wrist-flexion; and / or 3) shooting with an increase in knee extension velocity. Likewise, invariants (common to the variability-of-practice-hypothesis) were not held constant but were varied, too. The variations not only concerned movement executions, but also the target. The constant practice group shot 50 free throws without any instructions.

Experiment 2. Fourteen active elite volleyball players (n = 6 men and 8 women; mean age: 23.7 ± 2 years, mean weight: 84.1 ± 6.5 kg, mean height: 193.2 ± 8.5 cm, mean training age: 6.3 ± 2 years) of top national volleyball league standard participated in the current study. Original sample size was 16; however, due to injury two players could not take part in the post test.

Research design. Players were assigned to one of the two intervention groups (i. e., seven players each) who practiced the strike over a period of 18 sessions (two sessions per week; 25 strikes each session) additionally to the regular training.

Intervention group 1 (IG1-VB) practiced according to the differential learning approach. In contrast to the first experiment, the intervention-induced variability was not only achieved by diverse executions but also by perturbations created through elastic cords (Figure 1a). Examples for such cord positions would be 1) from the left anterior superior iliac spine to the upper arm; 2) from left anterior superior iliac spine to the wrist and elbow; and 3) from the ilio-sacral joint to the upper arm and the left ball. Variability was further enhanced by the altering cord position and length.

Seventeen of the 25 strikes were practiced with cords; the remaining 8 strikes were practiced without cords. The second intervention and quasi-control group (IG2-VB) practiced their strikes according to constant practice. Pre- and post-tests consisted of one constant and one variable test situation in which the participants were told to strike at the given target as fast and accurately as possible. The four target positions used were equivalent to positions in volleyball (see Figure 1b). In the constant test situation, participants had to strike 10 shots at position 1. In the variable test condition, participants were required to strike a total of 16 shots at four predetermined targets in random order.

The training device (Tendybelt ®, Salzburg, Austria) is a specially designed chest belt tied around the waist with loops at the front and back and a hook-and-loop fastener at the front (Figure 1a). The cords used in this study were different thera tubes (*Thera-Band ® GmbH*, Dornburg-Frickhofen, Germany). The cords were used in order to increase variability in reactive phenomena within an optimal solution space.

Ball velocity and accuracy were measured to determine performance increase. Velocity was measured using an ALGE speed system (*ALGE Timing*, Lustenau, Austria). To measure accuracy, deviations were calculated according to a coordinate system. This coordinate system was virtually spanned over the entire volleyball court with the base line representing the y-axis and the side line as x-axis.

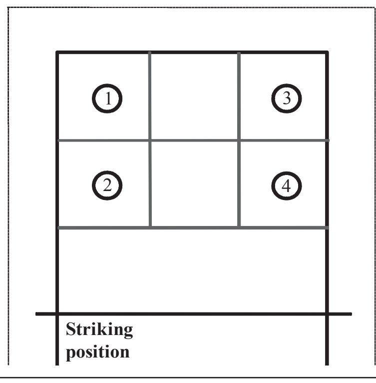
Statistical analyses. Statistical calculations for both experiments were performed using PASW 18 (SPSS Inc., Chicago, IL., USA). All significant differences reported were at $p < 0.05$. Data were checked for normality (Kolmogorov-Smirnov test), sphericity and reliability were calculated for the accuracy test in volleyball. Means and 95%-confidence intervals were calculated using conventional statistical measures. A two-way repeated measures analysis of variance (ANOVA) was employed to examine differences on each of the dependent variables. For the basketball experiment, a 3 (group) X 3 (time) ANOVA and for the volleyball experiment, a 2 (group) X 2 (time)

Figure 1 a. **Application of the elastic cords**

a

Note. The elastic cords were from the lower back to the right forearm and from the left hip to the right upper arm.

Figure 1 b. **Four targets and the subjects' striking position**



b

ANOVA were calculated. Independent variables for both experiments were group and time; dependent variables for the basketball experiment were successful shots and sum of points; for the volleyball experiment they were strike velocity and strike accuracy. Simple contrasts were calculated to reveal group differences. Effect size partial eta squared (η_{p^2}) was calculated to measure the degree of meaningfulness. Graphs were created using OriginPro 8.0 (*OriginLab Corporation*, Northampton, USA).

RESEARCH RESULTS

For the basketball experiment, similar results were found across the three groups for pre-, post- and retention tests. Data with respect to the sum of points showed no statistical differences among all three groups ($p > 0.90$; $\eta_{p^2} = 0.01$; Figure 2 a). Post hoc analyses for each age group (i. e., junior and under-16) demonstrated similar results with marginal, non-significant effects (junior: $p > 0.70$; $\eta_{p^2} = 0.04$; under-16: $p > 0.90$; $\eta_{p^2} = 0.03$).Simple contrasts between groups revealed no significant differences for sum of points (IG1-BB vs. CG: $p > 0.67$; $\eta_{p^2} = 0.01$; IG2-BB vs. CG: $p > 0.78$; $\eta_{p^2} = 0.01$; IG1-BB vs. IG2-BB: $p > 0.96$; $\eta_{p^2} = 0.00$).

Analysing the transfer test situations, performance was lower for all three groups compared to post free throw and retention free throw tests; however, the differences between the groups were not statistically significant (TT 1: $p > 0.80$; $\eta_{p^2} = 0.01$; TT 2: $p > 0.30$; $\eta_{p^2} = 0.05$). Additionally, the time X group interaction showed no significant results for the jump shot ($p > 0.20$; $\eta_{p^2} = 0.06$) (Figure 2 a). Otherwise, simple contrasts between groups revealed appreciable effects for the transfer situation comparison of IG1-BB versus CG, as IG1-BB showed superior performance ($p > 0.10$; $\eta_{p^2} = 0.09$). No such effects were found for the comparison of IG2-BB to CG ($p > 0.60$; $\eta_{p^2} = 0.01$) and the IG1-BB to IG2-BB ($p > 0.30$; $\eta_{p^2} = 0.03$).Results for successful shots show similar results as those for sum of points.

In the volleyball experiment, results unveiled a significant advantage with respect to velocity for the elastic cord group in variable situations ($p < 0.05$; $\eta_{p^2} = 0.36$), whereas constant situations did not reveal similar results ($p > 0.50$; $\eta_{p^2} = 0.03$) (Figure 2 b).

For the accuracy test, a reliability of 0.42 was found. Calculated results did not show significant differences for the constant or variable situation ($p = 0.05$; $\eta_{p^2} < 0.26$).

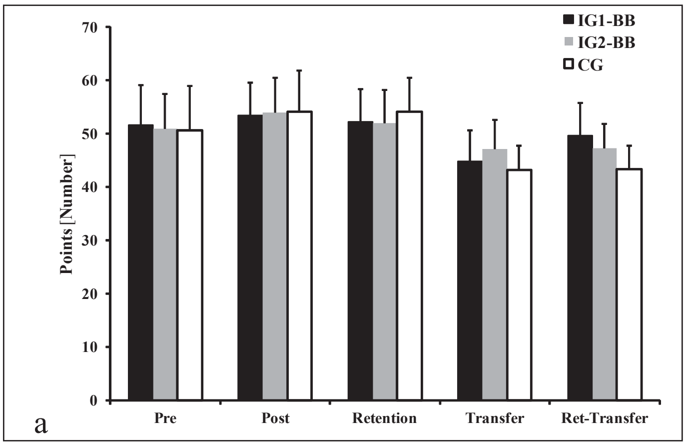


Figure 2 a. **Mean values for the sum of points for all three groups at all test times**

Note. * – indicates a significant increase in performance; ▲ – indicates difference between groups (error bars represent 95% – confidence interval).

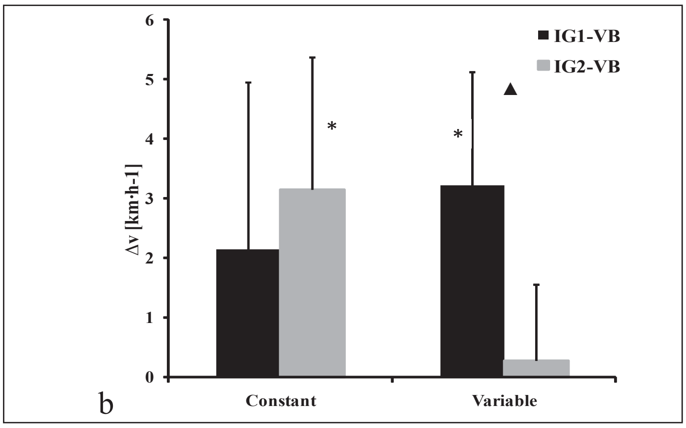


Figure 2 b. **Mean group changes for velocity in the constant (left) and variable (right) situation**

DISCUSSION

Summarizing the two experiments, differential learning shows advantages in variable and transfer situations, but constant training situations do not yield similar results.

The findings in the free throw experiment might be considered surprising given previous research on the same basketball skill (Schönherr, Schöllhorn, 2003), which demonstrated a performance advantage for differential learning after acquisition phase (participants were about the same age, however, they had a low level of performance).

Notwithstanding the above, results in transfer tests represent a small advantage for the intervention groups over CG. Calculating the percentage of transfer (PoT) (Magill, 2004), both IG1-BB and IG2-BB show a positive transfer compared to CG. In the first transfer test, IG2-BB demonstrates better transfer than IG1-BB (+2.6% for points and +5.3% for number of shots), but it was outperformed in the second transfer test by IG1-BB (+2.4% for points and 5.8% for number of shots), reflecting a continuous positive trend in performance increase in the transfer situation. This would be in line with the idea of different variable practice concepts where positive effects are observed on transfer tasks, and it may take until the retention test to observe an advantage in performance (Brady, 2004; Memmert, 2006; Schöllhorn et al., 2006; Schöllhorn et al., 2009 a).

For the volleyball strike, the intervention-induced variability through different cord applications resulted in a superior learning effect with respect to velocity in variable situations. In the constant test situation, both groups improved their performance, with the standard training group showing similar performance in strike velocity. As a reliability of 0.42 for the accuracy test is unqualified to fulfill the criteria to offer any particular information (Bortz, Döring, 2002), the results of the accuracy data will not be considered in the following discussion.

Nonetheless, the question to be answered is why variable practice in volleyball and basketball should lead to proficiency that outperforms constant practice in the long run not only in variable situations but in constant situations as well.

As such approaches as neurobiology or artificial neural networks illustrate, a central issue is the adaptation of the human nervous system and the extraction of rules (i. e., generalization ability). Already during the very early stages of life, we learn due to our generalization ability. Babies neither learn to talk nor do they learn to walk or run by instructions (Adolph et al., 2003). Instead, their nervous system automatically extracts the underlying similarities and generalizes the experiences in such a way, that they learn to walk or talk without explicitly knowing the underlying "rules".

The same can be applied to skills in sports. Volleyball or basketball players do not acquire the same flexibility and adaptability of their strike / shot (adequate for the different situations occurring during the game) through constant repetition than through variable training. Rather, different stimuli permit the development of the required skill for the dynamic game situation. One must take into account that in volleyball and basketball no situation is alike because there is a rapid and permanent change due to different game situations and different opponents (Lames, McGarry, 2007). The acquisition of an appropriate "rule" that allows the best movement outcome for the actual situation (i. e., good generalization) should be ensured through diverse executions (Schöllhorn et al., 2009 a).

Concerning the constant test situation, the variability in IG1-BB and IG1-VB (i. e., the combination of the athlete's inherent variability and task variability due to the set constraints) probably exceeded the optimal amount of movement variability for this task. The transfer of variable practice to a constant situation did not occur accordingly, leading to no superior performance compared to the other groups. Therefore, variable training seems to be less adequate for "constant" situations. Nevertheless, our analyses unveil rather opposite results compared to other differential learning studies, which all report better performance even in constant test situations (e. g., Schöllhorn et al., 2006).

Although variations that do not typically occur in the game were purposely set (such as deliberately missing the basket by shooting at the right rim, that is, participants were also purposely asked to execute errors), players could not enhance their performance to that effect. As for the basketball experiment, no intervention group showed increase in performance; therefore, it can be concluded that the level remained the same (i. e., there were no negative interferences due to the applied perturbations).

Concerning the variations used in this study, it could be assumed that the differences were not appropriate for such a goal (i. e., the free throw) and that with respect to this goal the exercises were no longer interacting with each other. As research on the contextual interference effect (Brady, 2004) or differential learning (Birklbauer et al., 2006; Frank et al., 2008) demonstrated the existence of an optimal amount of variability. It appears that the solution space, which includes the diverse executions, spans over a different area of (execution) variability for constant tasks in comparison to variable tasks. Therefore, with respect to movement, the solution space must then be adequately chosen (Birklbauer et al., 2006).

This optimal amount of variability not only depends on various moderator variables (e. g. training age, skill level, experience, physical condition) (Haudum et al., 2009; Schöllhorn et al., 2009 a), but also on the available time (i. e. whether one analyses the short or long term effect of practice). For our intervention studies, the time was perhaps too short to benefit from the induced variations. If time is limited, the natural variability within a shot or strike in the "constant" situation might be enough for a performance increase. The disadvantage is that if there is a change in technique, equipment or other constraints constant practice will not allow for appropriate adaptation due to the constant training situation. However in the long run, larger differences that decrease over the progress of training will later allow finer variations (Schöllhorn et al., 2009 a), which then may result in an establishment of superior performance.

So, for the constant situation in the volleyball experiment (wherein natural task variability was higher than in the basketball experiment's free throw situation), the "normal" variability in the IG2-VB seemed to be equally effective in this period of time as IG1-VB, as both increased their performance, but none could outperform the other intervention group. However, it cannot be concluded that variable training is not efficient in constant situations in the long run. Studies to investigate the effect of variable practice in constant situations over a longer period of time are needed to give solid advice.

An apparent aspect, especially in the free throw experiment, is the number of shots performed during the intervention. Since participants had a certain training age and assuming that the participants had already practiced hundreds of free throws prior to the intervention (and perhaps have established their individual routine prior to the shots), the intervention-induced variability could not be successfully transferred to the free throw in this short period of time. Since the process to become an expert needs thousands of shots (Baker et al., 2003), the additional practice time in form of this intervention might have been too short to reflect an increase in free throw performance on such level of play. This underpins that performance enhancement at a certain skill level, especially for "constant" skills, takes time and enhances number of shots.

CONCLUSION AND PERSPECTIVES

In conclusion, the intervention-induced variability leads to benefits in variable situations, whereas for rather constant situations (i. e. basketball free throw), it seems to require a different amount of induced variability. For the free throw, performance was similar for both intervention groups; however, for the variable transfer task situation (i. e. jump shots) a positive tendency occurred in form of an outside transfer of the variable training situation.

ACKNOWLEDGEMENTS

The authors would like to thank Roland Schwab and Romana Ebner for their support.

REFERENCES

Adolph, K. E., Vereijken, B., Shrout, P. E. (2003). What changes in infant walking and why. *Child Development,* 74 (2), 475–497.

Baker, J., Cote, J., Abernethy, B. (2003). Sport-specific practice and the development of expert decision-making in team ball sports. *Journal of Applied Sport Psychology,* 15 (1), 12–25.

Bernstein, N. A. (1967). *The Co-ordination and Regulation of Movements*. Oxford: Pergamon Press.

Birklbauer, J., Haudum, A., Müller, E. (2006). *Contextual-Interference-Approach versus Differential-Learning-Approach*. Paper presented at the 11th Annual Congress of the European College of Sport Science, Lausanne.

Bortz, J., Döring, N. (2002). *Forschungsmethoden und Evaluation für Human- und Sozialwissenschaftler*. Heidelberg: Springer.

Brady, F. (2004). Contextual interference: A meta-analytic study. *Perceptual and Motor Skills,* 99 (1), 116–126.

Button, C., MacLeod, M., Sanders, R., Coleman, S. (2003). Examining movement variability in the basketball free-throw action at different skill levels. *Research Quarterly for Exercise and Sport,* 74 (3), 257–269.

Frank, T. D., Michelbrink, M., Beckmann, H., Schöllhorn, W. I. (2008). A quantitative dynamical systems approach to differential learning: Self-organization principle and order parameter equations. *Biological Cybernetics,* 98 (1), 19–31.

Haudum, A., Birklbauer, J., Kröll, J., Schwab, R., Müller, E. (2009). *Induced increase of system immanent variability through an elastic cord technique training device and a practical application.* Paper presented at the 14th European Congress of Sport Sciences, Oslo, Norway.

Lames, M., McGarry, T. (2007). On the search for reliable performance indicators in game sports. *International Journal of Performance Analysis in Sport,* 7 (1), 62–79.

Magill, R. A. (2004). *Motor Learning and Control.* 7th ed. New York: McGraw-Hill.

Memmert, D. (2006). Long-term effects of type of practice on the learning and transfer of a complex motor skill. *Perceptual and Motor Skills,* 103 (3), 912–916.

Schöllhorn, W. I., Mayer-Kress, G., Newell, K. M., Michelbrink, M. (2009 a). Time scales of adaptive behavior and motor learning in the presence of stochastic perturbations. *Human Movement Science,* 28 (3), 319–333.

Schönherr, T., Schöllhorn, W. I. (2003). Differencial learning in basketball. In W. I. Schöllhorn, C. Bohn, J. M. Jäger, H. Schaper, M. Alichmann (Eds.), *1st European Workshop on Movement Science* (pp. 58–59). Cologne: Sport & Buch Strauß.

Schöllhorn, W. I., Michelbrink, M., Beckmann, H. et al. (2006). Does noise provide a basis for the unification of motor learning theories? *International Journal of Sport Psychology,* 37 (2 / 3), 34–42.

Schöllhorn, W. I., Michelbrink, M., Welminsiki, D., Davids, K. W. (2009 b). Increasing stochastic perturbations enhances acquisition and learning of complex sport movements. In D. Araujo, H. Ripoll, M. Raab (Eds.), *Perspectives on Cognition and Action in Sport*. Nova Science Publishers, Inc.

Spratte, M., Janssen, D., Schöllhorn, W. I. (2007). *Recognition of jumping patterns in volleyball after traditional and differential strength training by means of artificial neural nets.* Paper presented at the 3rd European Workshop on Movement Sciences.

DIFERENCIJUOTO MOKYMO POVEIKIS JUDĖJIMO ĮGŪDŽIAMS LAVINTI

Anita Haudum, Jürgen Birklbauer, Kröll Josef, Erich Müller
Zalcburgo universitetas, Zalcburgas, Austrija
Christian Doppler laboratorija „Slidinėjimo biomechanika“, Zalcburgas, Austrija

SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Ir sportininkas, ir treneris turi tą patį tikslą – pagerinti sportinį parengtumą.

Tikslas: nustatyti, kaip diferencijuotas mokymas veikia baudų metimų (žaidžiant krepšinį) ir kamuolio atmušimo (žaidžiant tinklinį) rezultatyvumą.

Metodai. Tiriant krepšininkus (prieš eksperimentą, po jo ir po judesio įgūdžio išlaikymo) buvo registruojami baudos metimai (sėkmingų metimų skaičius). Norint nustatyti judesio įgūdžio pritaikymą žaidžiant krepšinį buvo registruojami metimai pašokant. Tiriant tinklininkus kamuolio atmušimo kaitumas buvo didinamas apribojant rankos judesį (naudotas elastinis pasipriešinimas). Antroji intervencinė ir kvazikontrolinė grupės treniravosi įprastomis treniruotės sąlygomis. Kamuolio greitis ir metimų tikslumas buvo analizuojami taikant pastovumo ir kaitumo testus.

Rezultatai. Jokių reikšmingų skirtumų neaptikta tiriant baudos metimus ($p > 0,05$) ir įgūdžių perkėlimo situacijas ($p > 0,05$). Tačiau kaitumo grupėje buvo pastebėta teigiama tendencija įgūdžių perkėlimo pratybose. Diferencijuotas mokymas pagerino tinklininkų kamuolio atmušimų greitumą atliekant kaitumo testą ($p < 0,05$), tačiau atliekant pastovumo testą ($p < 0,05$) ir tiriant metimų tikslumą ($p < 0,05$) panašių rezultatų negauta.

Aptarimas ir išvados. Abiem eksperimentais nustatyta judesių lavinimo, taikant kaitos principus, reikšmė, ypač svarbi pritaikant judesių įgūdžius kintamomis sąlygomis. Visgi, ypač pastovumo situacijose, reikia atsižvelgti į tokius tarpinius kintamuosius kaip amžių ir kitų sporto šakų kultivavimą, dalyvavimą fizinėje veikloje norint pritaikyti tinkamą išorinį ar intervencinį kaitumą.

Raktažodžiai: diferencijuotas mokymas, kaitumas, prisitaikomumas, žaidimai su kamuoliu.

Gauta 2010 m. rugsėjo 14 d.
Received on September 14, 2010

Priimta 2011 m. kovo 17 d.
Accepted on March 17, 2011

Corresponding author **Haudum Anita**
Department of Sport Science and Kinesiology, University of Salzburg
Christian Doppler Laboratory “Biomechanics in Skiing”
Rifer Schlossallee 49
5400 Hallein-Rif
Austria
Tel +43 650 50 60 41 8; +43 662 80 44 48 82
E-mail anita.haudum@sbg.ac.at