BIOMECHANICAL ANALYSIS OF PERFORMANCE IMPROVEMENT IN AIMING MOTOR TASKS

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INTRODUCTION: Aiming ability is very important to a large number of sports (e.g., basketball) and can be improved through practice. Its evaluation usually depends on the changes in performance scores of specific motor skills. However, a performance score is only the output of the motor system's activation, which provides the necessary muscular forces to execute and control the movement. It is well established that many combinations of the muscular system's activation patterns may result in the same performance outcome (Hobart et al., 1975). Some of these combinations may necessitate excessive energy and time consumption and should be avoided, especially when high performance scores are expected to be produced in a large number of subsequent trials. Thus, practice should lead to optimal modifications in the muscular activation pattern which should result in the improvement of aiming ability with low energy and time cost (Schmidt, 1988).
Some studies in the past have tried to determine the optimal modifications in the kinematic patterns and found a decrease in the time and displacement of the movement (Landa, 1979; Vorro et al., 1978), while acceleration was either increased (Landa, 1979) or increased (Vorro & Hobart, 1974). The findings of previous studies regarding the myoelectrical modifications were more confusing.
Agonist activity was found to increase (Vorro et al., 1978), decrease (Hobart et al, 1975) or show no difference after practice (Landa, 1979), while the antagonist activity was found to increase (Hobart et al., 1975). Some studies also found an improvement in the agonist-antagonist coordination (Hobart et al., 1975; Corcos et al., 1989), while others found the same parameter to be worse after practice (McGrain, 1980).
The purpose of this study was the identification of the kinematic and myoelectrical modifications which lead to the improvement of performance in aiming motor skills after practice.

METHOD: Seventy-two males and females, aged between 18 and 23 years, served as voluntary subjects. A mechanical apparatus (Figure 1) was constructed to restrict the motion to a single plane, thus increasing the accuracy of measurement.
The subjects sat on the seat and placed their right upper limb along the two beams, secured by the wrist cuff and by two inelastic straps. The height of the seat was adjustable so that the subject's upper arm could rest in an horizontal position. The subjects were asked to throw a small ball from the cup to the center of the graded target, performing elbow flexion. Performance scores were determined as the magnitude of the deviation between the landing point of the ball and the center of the target. The direction of the score values was determined by positive (above center) or negative (below center) signs.

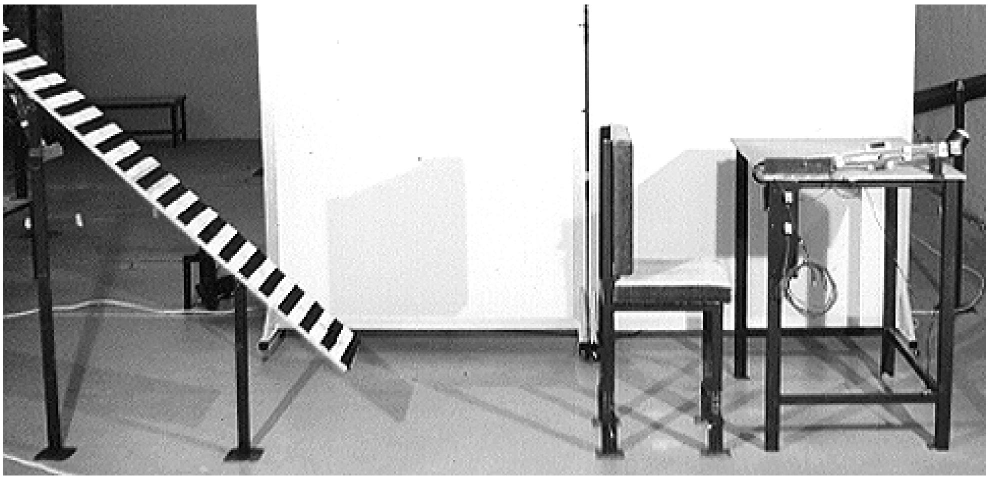

Figure 1. The mechanical apparatus used for the experiment

The subjects performed five trials which were regarded as pre-practice data. Eighty additional tosses were made and post-practice data were gathered on five additional trials, at the end of practice. The motor skill was filmed by a high speed camera (Biomechanics 500, PhotoSonics), and the filming rate was set at 80 Hz. The raw kinematic data was extracted by a film digitizer (Numonics) and were digitally filtered with a cut-off frequency of 6Hz. The kinematic variables were computed though mathematical differentiation.
The electromyograghic waveforms (EMG) were recorded with 8 mm bipolar silver-surface electrodes placed at an inter-electrode distance of 10 mm. The electrodes secured with double-sided sticky rings over the muscle bellies of the biceps brachii, the brachioradialis, the medial head of the triceps brachii and the anconeus. Skin resistance was maintained below 20(103 Ohms through sand-paper abrasion and alcohol cleansing. Myosystem 1004 by Noraxon OY was used for the amplification and processing of the EMG signals. The sampling frequency was set at 1000 Hz. The signal was rectified and then filtered by a band-pass filter (10 to 250 Hz) to minimize aliasing effects. The signal was then integrated with a time constant of 10 msec and stored on a computer for subsequent analysis.
An electrical circuit involving two microswitches and two lambs was constructed for the synchronization of the EMGs and the filming events. Correspondence analysis was employed for the statistical treatment of the data.

RESULTS: Prior to the statistical analysis the differences between the pre-practice and the post-practice data were computed. The factors extracted through the correspondence analysis revealed that there were specific modifications of the kinematic and the myoelectric variables which were highly related to the improvement in accuracy after practice.
The results revealed that the second factorial axis (eigenvalue=0.299) primarily described the typology of the performance improvement and the modifications of the kinematic variables after practice. This typology is presented in Table 1.

Table 1. Kinematic modifications for the improvement of aiming after practice.

Variable	Change	Coordinates	Contributions
Time to ball release	decrease	0,83	5,2
Time to peak velocity	decrease	1,05	7,2
Time to peak acceleration	decrease	0,47	1,4
Displacement of ball release	decrease	0,61	2,4
Displacement of peak velocity	decrease	0,79	3,7
Peak acceleration	increase	0,85	4,2
Mean acceleration	increase	1,02	6,1

The respective typology for the myoelectrical variables (Table 2) was based on the first axis (eigenvalue=0.022).

Table 2. Myoelectrical modifications for the improvement of aiming after practice.

Variable	Change	Coordinates	Contributions
Biceps brachii premovement EMG	decrease	-0,20	1,3
Biceps brachii postmovement EMG	decrease	-0,41	5,5
Brachioradialis premovement EMG	decrease	-0,17	0,9
Brachioradialis postmovement EMG	decrease	-0,20	1,2
Triceps brachii emg activity	stopped	-0,55	2,0
Anconeus postmovement EMG	increase	-0,26	2,2
Time between the beginning activity of biceps & anconeus	increase	-0,28	2,5

DISCUSSION: The improvement in performance was coupled with significant modifications in the electrical activity of the muscles responsible for the accomplishment of the specific motor task. The agonists demonstrated a significant decrease in their electrical activity prior to the beginning of the movement. As a result the subjects required less agonist activity to begin the movement after practice.

Practice also resulted in a significant reduction of the electrical activity of the two agonists during the movement. This revealed that smaller number of motor units might be required for the execution of the motor task after practice, which might be interpreted as less muscle energy consumption (Basmajian & de Luca, 1985).

In addition the number of the active antagonists was reduced as the triceps stopped its activity after practice. As a result the anconeus had to increase its activity in order to control the action of the agonists (Corcos et al., 1989). However anconeus began its activity farther from the beginning of activity in the agonists after practice. So the co-activation of the antagonistic muscles was significantly diminished after practice, as the nervous system was provided with information to modify the reciprocal inhibition control scheme (Basmajian & de Luca, 1985; Hobart et al., 1975).

The myoelectrical modifications gave rise to specific alterations in the physical aspects of the skill, which directly resulted in improved performance. These involved the decrease of the displacement at the release of the ball after practice,

which resulted in a lower height of release and permitted better control of the ball trajectory after practice (Hobart et al., 1975; Landa, 1979).
Finally, practice resulted in the decrease of the time between the beginning of the movement and the release of the ball. This was in accordance with the findings of other studies and is considered to be the primary condition to improve accuracy in ballistic motor skills (Hobart et al., 1975; Landa, 1979).

CONCLUSIONS: The determination of the changes in the muscular activity and kinematics of the motor skill constitutes a reliable basis for the proper evaluation of several practice protocols and the precise assessment of the improvement of aiming as well. The identification of the contributing kinematic and myoelectric parameters and their relation to the improvement of aiming may enable coaches and teachers to give more pertinent feedback or information to their subjects. In this way the training process could be enhanced and the trial-and-error component of practice would be minimized.

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