Kinematic changes during development of a generalized motor program

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Introduction

The Motor Programs theory describes the process by which the nervous system activates control of voluntary movements. After making a decision the brain operates an action plan that directs the appropriate muscular activity. Keele (1968) defined the Motor program as a system of muscle commands created in advance and stored in memory. The Generalized Motor Program (GMP) concept developed by Schmidt (1975) is described as a more flexible and abstract mechanism that controls a class of actions having the same basic characteristics (throwing, kicking) or enables an adaptation of the performance to the environmental demands.

The GMP is developed through practice and becomes the basis for generating responses within a class of movements that share the same invariant features (e.g., sequencing, relative timing, and relative force). The invariant features are the basic representation of the action group in motor memory. The invariant characteristics are the order of the muscles activated, the relative timing of muscular activity, and the relative force of the muscles. The parameters are movement time, overall force, and muscle selection.

Some aspects of GMP were examined in the laboratory. Shapiro et. al (1981), using kinematic analysis, found that the relative timing did not change when the movement time was accelerated in walking and running. In a longitudinal study, Roberton & Halverson (1988) examined the stability of several features of the hopping skill, in children aged 3-15. Then found that some features were stable from the early trials while other features changed as the subject passed through different motor development stages. Maraj et. al (1993) found that components of the triple jump skill were unstable in new performers, while stable in experienced performers. Moor & Marteniuk (1986) examined kinematic and electromyographic changes in the learning process of the throwing movement. Results have shown differences among different components regarding the stability during practice. In a study by Brown & Bronks (1991), the causes of errors in performing simple laboratory skills were examined using EMG. They found that errors were caused by the mode of muscular contraction. Some were caused by the different relative timing and some were related to the intensity of the contraction.

The purpose of this study is to examine the development of the GMP and its
stability during the acquisition and retention of the soccer-kicking skill, by analyzing the kinematics and EMG changes in all categories of the invariant features.

Method

Twelve novice female PE students (ages 20-23) volunteered to participate in the study. The subjects were asked to kick a rubber ball toward a target on a wall; the target was positioned 1.5m above the ground and the subjects were 6 meters from the wall. The subjects participated in eight weekly sessions of 10 kicks each. Data was collected at the beginning and end of each trial and after a two-week of retention period (RP). The variables tested included the preparatory phase (PP), which is the time from the release of the ball and start of foot movement; movement time (MT), which is the time from foot-lift to foot-impact with the ball; the timing (sequence) of activation of the vastus medialis (VM), Hamstrings (H), Tibialis Anterior (TA), and Lateral head of Gastrocnemius (LG), and the percentage of the work load activation (WL) of the muscles used in the task during MT.

Results & Discussion

The timing of the PP kept improving and was shortest during the RP, however, the MT stabilized in post testing and maintained itself during the RP (Figure 1).

![Figure 1. Preparatory Phase (blue) and Movement Time (green) during initial (pre), after (post) training and Retention Periods.](image)

As shown in Figure 2, TA and LG muscles switched their order from the time points marked as #2 and #3 to #4 and #3 respectively in the sequence of activation during pre-testing, post-testing and RP. The H maintained activation as the initiator.
of the kick and followed by the VM before the ankle muscles were activated. The
time phases between each muscle activation were shortened and more consistent in
RP. The WL of the muscles was quite similar for each testing session, except for

the VM, which increased its % activation from 28% to 52% in post-testing and remained at 50% during RP.

Figure 2. Activation pattern/order of the muscles during different testing stages

The findings of the current study show that the constant practice participants were
successful at parameterizing their responses during the retention test. In fact that
this test required the same parameter specification as during acquisition is
consistent with the notion of the independence of the GMP and parameters.

Kinematical and muscular changes observed during the study, showed stabilization
of the invariant features towards the RP. This finding reinforces a similar premise
of the GMP theory.

References


Shapiro, D.C.; Zernicke, R.F.; Gregor, R.J.; Diestel, J.D. Evidence for


