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Sorting Through the Motor Performance Abilities Maze

by Christine M. Brooks

ABSTRACT

A motor skill is learned while a motor ability is a genetic characteristic. An athlete's success depends on how well foundational motor performance abilities - endurance, strength, speed, coordination and flexibility - are applied to performing the movement units encompassed in the skill required for his/her event. For the purpose of training programme design it is important to understand how these foundational abilities and derived motor performance abilities, such as anaerobic endurance, muscular endurance, power, speed of response, and acceleration, fit together. However, discussions in this area often slip into a confusing jumble of terminology. In this paper, the author, an experienced coach educator, offers a general guide to this maze. The Bös motor performance abilities model is used to classify motor abilities as either energetically determined or information oriented. It is then shown how the foundational motor performance abilities contribute to the derived motor performance abilities. Finally, using hurdling as an example, the process of conducting a needs analysis of an event for its relevant motor performance proficiencies is illustrated.

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Introduction

An athlete's success in any track and field event depends on how well the five foundational motor performance abilities[2] are applied to performing the movement units encompassed in the skill. Foundational motor performance abilities include endurance, strength, speed, coordination and flexibility. A coach uses these foundational motor performance abilities to develop the relevant derivatives of anaerobic endurance, muscular endurance, power, speed of response, acceleration, etc.

It is important for beginning and intermediate coaches to understand how the foundational and derived motor performance abilities fit together because this provides the clues that guides decision about training programme design. Discussions in this area often slip into a confusing jumble of terminology. To help the coach sort through the motor performance ability maze the following topics are addressed in this paper:

- the characteristics of an ability versus a skill;
- the five foundational motor performance abilities underlying the proficiency requirements for performing track and field skills;
- the derived motor performance abilities relevant to performing the movement units of the skills;
- how to identify the critical motor performance abilities and their derivatives for an event.

At the end of the article I provide a link to a teaching module on this topic.

Motor Skill Versus Motor Ability

The terms motor skill and motor ability are often muddled in sport. A motor skill involves the manipulation of the body parts to achieve a specific goal[3]. Performing rotational turns to impart the correct resultant velocity to a discus is an example of a motor skill. Positioning and timing the arms, legs, head and torso in order to clear a hurdle quickly is another example. In each case, the coaching task is to examine the movement units of the skill, then determine the specific motor abilities required, and finally decide on the most effective way to enhance them. Perfecting the movement units of any skill demands considerable rehearsing, cognitive activity, decision making, problem solving, remembering, etc. before the athlete can sequence them with the correct timing and rhythm to accomplish a superior outcome. The athlete's motor abilities sets the limit for how well the movement units can be performed to meet the demands of the event better than competitors.

Unlike a skill that is learned, an ability is an innate characteristic[3]. The term motor ability refers to abilities associated with performing motor skills. Motor abilities are the building blocks of motor skill and some athletes have higher quality building blocks than others providing them with more potential for performing the skill at an elite level. If two athletes have the same amount of practice, the same quality of instruction, and the same motivation to perform the skill, the one with the highest level of relevant motor abilities will perform the skill at a higher level and is therefore likely to have a more successful outcome in terms of competitive performance.

General Versus Specific Motor Abilities

There is no such thing as a general all-round 'global' motor ability. We are all born with a range of many independent motor abilities. Athletes who appear to be 'all-round' have inherited a high capacity to develop the motor abilities that form the foundation of many sports skills. The decathlete and heptathlete take advantage of their relatively high inherited capacity for endurance, speed, strength, coordination and flexibility .

Identifying the Foundational Motor Abilities

There are hundreds of motor abilities. The major coaching task becomes one of identifying the abilities that are most important for producing a superior performance. In athletics, five foundational motor abilities dominate. These include endurance, strength, speed, coordination and flexibility. Tudor Bompa, a Romanian biomechanist teaching in Canada, used the term 'biomotor ability' to describe these foundational abilities[4]. It is not clear why Bompa substituted 'biomotor' for 'motor performance ability'. In biotechnology "biomotor" refers to molecular proteins such as the myosin heads within the muscle's sarcomere. There are many different biomotor proteins in the human body. The term "biomotor" is also used to describe engines powered by environmentally friendly fuels. The human body certainly uses environmentally friendly fuels. So, we could argue there is some logic to using the term "biomotor" in reference to strength, speed, endurance, coordination and flexibility. However, we will use the term 'motor performance abilities' rather than 'biomotor abilities' because it is more accurate motor control terminology.

A Useful Model

The motor performance abilities of endurance, strength, speed, coordination and flexibility are called 'foundational' because they underlie the abilities needed to perform the movement patterns for many sports, including athletics. However, foundational motor performance abilities are not particularly useful in their pure form. For example, an athlete's maximal strength capacity is not the issue in successfully performing any athletics skill. Rather, it is the application of strength, in the correct amount, and in the appropriate form that is important. For this reason, the derivatives of foundational motor performance abilities are the more relevant competencies.

One approach to understanding the derivatives of the foundational motor performance abilities is offered by Bös1 (Figure 1). He clustered the five foundational motor performance abilities into two groups depending on whether they are primarily energy system or nervous system based. We could argue endlessly about all the negative nuances of using this categorisation. However, it is a useful starting point for the insight needed to analyse the motor proficiencies required for specific events.

Endurance, strength and speed have a large energy system component and are developed primarily through physical conditioning. Speed and coordination involve substantial nervous system input relying on effective information processing. Flexibility is an innate anatomical characteristic rather than a motor ability. Bös locates flexibility within the passive system of energy transfer because it permits more effective application of the other four foundational motor performance abilities.

Defining the Foundational Physical Performance Abilities

Let us quickly review some important aspects of the five foundational motor performance abilities.

Strength is the capacity to produce large amounts of force, regardless of speed of movement. Athletes have a different innate capacity for strength. This varies according to the cross-sectional area of the muscle, the type of fibre making up the muscle, the direction and length of fibres, and neurological control. The inherited proportion ranges from 30% to 95% depending on the contraction type, speed of contraction, and specific muscle group[5].

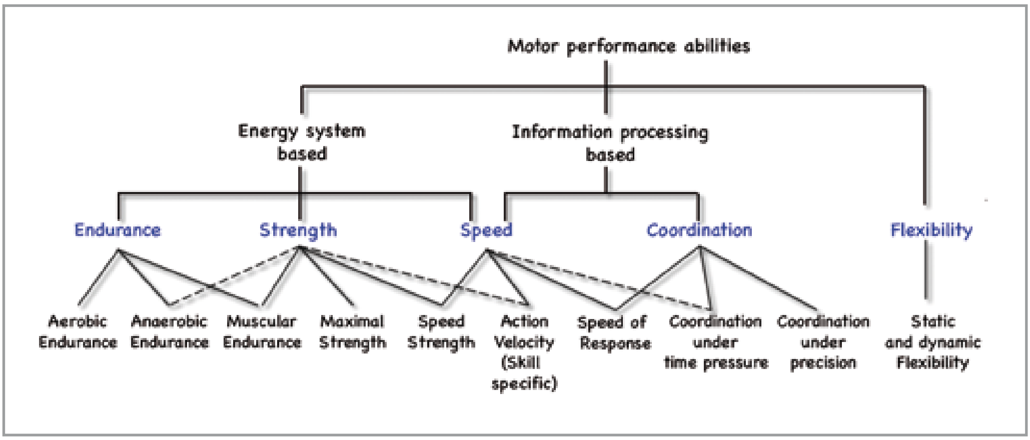

Figure 1: Foundational and derived motor performance abilities

Environmental factors, training and other lifestyle behaviours also play a role. Tasks that develop strength are often designed to stimulate improvement on the athlete's general strength capacity. Push-ups and sit-ups are examples of body weight exercises. Exercises using weights are also used to target development of an athlete's strength capacity[2].

Endurance refers to the ability to perform work of a given intensity over a period of time. Three different energy systems provide endurance capacity depending on whether the goal is to perform very high intensity work (the alactic and glycolytic energy systems), or lower intensity of work over a long period of time (the aerobic energy system). The capacities of all three energy systems have a strong genetic component[6].

Speed is the capacity to move the body and its parts very quickly[7]. Producing high speed requires precise neurological input to time the application and production of forces produced by muscles, skeleton and muscle-tendon 'springs'. The internal structure of bones, organs and muscle insertions, in addition to the external structure of the athlete's arms, legs and torso, all play a role in how fast the athlete can move. Most athletes can reach their maximal running velocity in 30 to 40m and maintain it for approximately three seconds[2]. Therefore, training tasks for developing maximal running velocity require an acceleration period of 30-40m and then maintaining that speed for periods of two - three seconds [2].

Coordination permits the athlete to synchronise two or more body parts[8]. You can think of coordination as the outcome of how well the athlete's brain solves the problem of effectively directing the muscles, joints and limbs to perform the movement units of a skill optimally and effectively. The body alters its general position in space by shaping and reshaping itself within milliseconds. The starting and stopping of body parts can occur almost concurrently, and they can occur asynchronously. Sport skills usually involve several muscles working in a perfectly timed sequence of movement units. Even the simple act of running demands that the leg muscles contract in different intensities, at different times, and in a specific sequence.

Like most sport skills, athletics skills consist of a string of movement units that must be precisely timed. The successful outcome involves setting the entire sequence of the movement units into action (sequence initiation), and establishing the time structure of the entire sequence (sequence rhythm). The brain also must form a representation of the sequence order for the movement units[9]. These three processes occur in different parts of the brain.

How the neuromuscular system works to optimally meet the task of coordinating the movement units of the skill has long puzzled motor control researchers. For example, when throwing the discus a thrower must learn the timing and rhythm sequence for shifting body weight over the legs in sequence with the rotary, flexion and extension movements of the trunk, shoulder, elbow, etc. In a young athlete who is just introduced to an event, the relative timing of each of these parts of the body involves many errors and is 'jerky' (i.e. it lacks the correct rhythm). Timing and rhythm eventually becomes fairly consistent, although even at the elite level there remains variability each time the movement units are performed.

Some athlete's are able to learn to initiate a sequence, develop the rhythm and form a mental representation of the sequence order very quickly. Some take a long time to do this. Some can reproduce complex motion very precisely when there is no time restriction. However, when producing the skill at the required speed, they cannot do it. The age of the athlete has an influence on coordination. During human development, coordination improves along with the maturation of the nervous system[10]. However, there is also a strong genetic influence in all these neural processes.

Flexibility is the ability to display high amplitudes of movement. It incorporates both static and dynamic components that permit optimal application of the motor performance abilities[11]:

- **The static** component involves moving slowly into a stretch position so as to avoid activating the stretch reflex. The muscle has the largest capacity for lengthening under static conditions. Stretching stimulates an increase in the number of sarcomeres and this, in turn, is thought to structurally lengthen the muscle fibre over time. The tendon, on the other hand, is limited in its lengthening capabilities. Static flexibility is typically developed with traditional stretching routines that require holding the body for extended periods of time in positions that challenge flexibility limits. Warmer tissues stretch more than colder ones. Coaches should make sure the athlete warms up thoroughly before stretching statically.

- **The dynamic component** involves moving a muscle quickly into a stretched position using high amplitudes of motion. Dynamic flexibility works within the confines of the Golgi tendon organs and muscle spindles. Muscle spindles lie parallel to the muscle fibres and monitor the tension and length of the whole muscle. Golgi tendon organs are located in the tendon and protect the tendon by inhibiting muscle contraction when stresses on the tendon become unsafe.

Together, the muscle spindles and Golgi tendon organs activate the stretch-reflex mechanism. When the muscle spindle is stretched, impulses are sent to the spinal cord that results in reflex muscle contraction. If the stretch is maintained longer than[6] seconds, the Golgi tendon organ fires, causing relaxation. Activities that train dynamic flexibility normally require moving one side of a joint through large ranges of motion while the other side of the joint remains stable. Examples are leg swings or arm circles[2]. The goal is to train a delay or minimise activation of the stretch reflex thus permitting higher amplitudes of motion.

Together these foundational motor performance abilities establish a level of work capacity that allows the athlete to withstand the training loads[2].

Derived Motor Performance Abilities

The five foundational motor performance abilities, in and of themselves, are not sufficiently specific in their application for successfully performing any single skill. Rather, they influence the development of relevant specific proficiencies such as starting and acceleration. An increase in sports achievement comes from the training that develops derived motor abilities. The Bös model identifies nine influential derived abilities (Figure 1). They include aerobic endurance, anaerobic endurance, muscular endurance, general strength, speed strength (power), skill specific speed, speed of response, coordination under time pressure and coordination with precision.

Aerobic endurance is relatively straight forward. Aerobic endurance is the ability to produce ample amounts of energy using the aerobic energy system. Activities that improve aerobic ability require the body to consume oxygen by exercising it at the lower intensities that use the aerobic system for energy production. The maximal oxygen uptake (VO2max) parameter reflects the ability of the cardiovascular, respiratory and musculoskeletal systems to capture, transport and use oxygen and has a strong genetic influence.

Anaerobic endurance, on the other hand, combines the two foundational motor performance abilities of endurance and strength. Anaerobic endurance is the ability to perform many repetitions of the same skill against a given resistance (usually gravity) for a prolonged period of time under two physiologic conditions. One condition involves shorter periods of time under neurological degradation that occurs once the body has reach maximal velocity. The other condition induces high acid conditions within the body. Long sprinters fit this criteria and train to clear and psychologically tolerate higher acidic conditions of the blood and cells. Anaerobic energy system development can be done using any activity sufficient to force the body to work of higher intensity so acid conditions are produced. When the distances are shorter and neurological degradation occurs, training typically consists of intense sprinting over distances of around 80m[2].

Muscular endurance is also derived from both endurance and strength and, like anaerobic endurance, is the ability to perform many repetitions against a given resistance. However, in this case the endurance component is only based into the ATP-PC system. The field events require muscular endurance if the athlete is to perform all the preliminary rounds and the final rounds. The short sprints also demand muscular endurance. In these cases the ATP-PC energy is stressed, and the athlete relies on the recovery of this system between rounds.

Maximal strength is solely based within the strength foundational motor ability. There is a neurological component initially. However, long-term development of maximal strength is energetically and structurally determined with a strong genetic influence.

Speed strength is derived from both speed and strength and based in both the energy system (ATP-PC) and the nervous system. It is the ability to produce force quickly. There are three main applications of speed strength in track and field:

- *To produce a change in direction very quickly using elastic energy and stretch reflexes.* This is often referred to as **reactive strength**. When running, for example, every time the foot lands on the ground the body is moving downwards. The leg must have sufficient reactive speed strength to brake the downward movement and accelerate the body upward and forward as quickly as possible. Reactive strength related tasks involve muscle tissue stabilizing in an isometric contraction, then stretching eccentrically under the force of impact, then contracting concentrically to perform work. Jumping activities are examples of activities that train reactive strength.

- *To produce high speeds of movement while overcoming some resistance.* This is referred to as **power.** All the throwing, jumping, and short sprints demand high power. Uphill sprinting and high speed weight exercises are examples of training activities that address power.

- *To produce the ability to effectively move the body from rest and approach maximal velocities within a specific timeframe.* This is the athlete's acceleration power. Most athletes are capable of reaching maximal velocity in 30 to 40m from a stationary start. For this reason, training tasks for developing acceleration power consist of short, intense sprints from a standing start[2] .

Skill specific velocity (action velocity) is also derived from the energy system (ATP_PC) and the nervous system but has a larger nervous system component. This is the preferred speed with which a sport speed is most effectively accomplished. Running between the hurdles, for example, demands a specific action velocity for producing the rhythm necessary to maintain high velocity. Jump approaches all require 'optimal' rather than maximal speed.

Speed of response, on the other hand is a relatively self-contained motor ability lying within the nervous system. It is determined by both speed and coordination under time pressure. Responding to a starting pistol is the most important application of speed of response.

Coordination under time pressure includes agility and mobility movements. These movements lie within the nervous system, and contain a significant speed component.

- Agility is the ability to perform irregular movements quickly and accurately. Tasks that develop agility include movements such as starting, stopping, and changing direction. All agility movements such as going over hurdles are performed with a time pressure component. They must be done very quickly.

- Mobility is the ability to display large ranges of movement in the joints, while accomplishing technical tasks. Mobility differs from dynamic flexibility because of the high level of technical demand associated with it. Activities designed to increase mobility generally require the body to perform technical movements that require high amplitudes of motions accurately. Hurdle walkovers are a good example[2].

Coordination with precision is strictly a nervous system derived ability that includes balance type tasks. This is included whenever the limbs are to be moved precisely such as in hurdling, the jumping events and throwing. It involves both balance and technical execution.

- Balance is the ability to remain stable. Balance developing tasks normally require the athlete to remain upright and stable in single support during stationary, walking, or skipping activities. Balance beam or wobble board exercises are example of balance building activities.

- Technical Execution is the ability to perform specific sports skills, repetitively with ease and accuracy. Improved technical execution results from rehearsal of the wide array of such skills a track and field athlete must possess be in order to perform at high levels.

In learning coordination, the first step is for the athlete to master motions in a stable environment, without time restrictions, focusing on improvement of precision. After the skill becomes formed, they can move to learning to do it more quickly while maintaining correct form and adapting to different situations and environments.

Conducting a Motor Performance Ability Needs Analysis

Developing the athlete's performance ability profile to match the skill requirements of the event is one of the major tasks of training programme design. Two factors determine the training time devoted to developing the five performance motor abilities and their derivatives:

- The ratio of each motor performance ability and its contribution to optimal performance.

- The strength or weakness of the athlete's essential motor performance abilities. A weak ability important for optimal performance will require focused training time.

The objective of a needs analysis for training is to merge the relevant derived abilities into a movement form that is required for success in performing the skill. For example, let's examine 100m hurdling. The key foundational motor abilities are very high speed and dynamic flexibility. All elite hurdlers are very fast and very flexible.

Flexibility is a critical characteristic that permits the athlete to manipulate body parts over the hurdle efficiently.

The skills of hurdling also demand the following five derived motor performance abilities:

$DMPA_1$ = Acceleration power (to get from the starting line to the first hurdle)
$DMPA_2$ = Coordination under time pressure (to clear the hurdle quickly)
$DMPA_3$ = Coordination under precision (to clear the hurdle effectively)
$DMPA_4$ = Anaerobic endurance (ATP-PC) system (to clear 10 hurdles over a distance of 100m)

Using this example we find that even if speed is increased, hurdling performance will eventually stagnate unless the derived motor performance abilities (DMPA1 – DMPA4) are addressed through training. Fast athletes do not always possess sufficient coordination under time pressure, or coordination with precision to become great hurdlers. Analysing the motor performance abilities relevant for hurdling makes it clear that a high level of nervous system input is necessary. Unlike pure sprinting, which is probably limited by the athletes speed potential, hurdling is more likely limited by their neurological potential. Speed is the underlying foundational motor performance ability. However, there are 10 barriers to negotiate between the start and finish line that demand exceptionally honed coordination abilities in order to clear them with high speed.

Teaching Module

Readers who are interested in video teaching module that explains the concepts outlined here may access it free of charge through the following link:

http://www.learnitez.com/HPeBook/PublicFiles/L7_Abilities/1_Introduction.html

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