0363-5465/78/0605-0232$02.00/0
THE AMERICAN JOURNAL OF SPORTS MEDICINE, VOL. 6, NO. 5
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Sport-specific performance factor profiling

Fencing as a prototype*

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It is the principal purpose of this paper to demonstrate the utility of profiling physical characteristics for athletes of a given sport, including a prediction of performance capabilities. A musculoskeletal profiling study is presented as a methodologic model, with the understanding that sport profiling is not limited to any single group of parameters. It is proposed that more comprehensive profiles covering anthropometric, cardiorespiratory, psychometric, musculoskeletal, and neurologic performance factors are technologically feasible. Such profiles have significant medical and competitive performance applications.

MATERIALS AND METHODS

The subject population for this model profiling study consisted of 24 male members of the 1975 U. S. Pan American and 1976 Olympic fencing squads.

Fencing is a sport that particularly lends itself to profiling studies. Fencers have a unique musculoskeletal development and their performance success is numerically measured.

The subjects were divisible into three equal groups according to weapon used: eight in foil, eight in épée, and eight in saber. Age ranged from 21 to 54, with a mean of 29. Fencing experience ranged from 4.5 to 40 years, with a mean of 14. The subjects uniformly demonstrated high motivation toward maximal profile test performance. They all restricted their regular sports participation exclusively to fencing.

While the fencers were in training for the aforementioned international competitions, the following data were obtained for each individual: (1) biographical information; (2) history of injury; (3) height and weight; (4) limb segment circumference measurements: arm, forearm, thigh, and leg; (5) musculoskeletal flexibility ratings (Nicholas)[1]; and (6) muscular strength, endurance, and power output for the following reciprocal muscle groups: knee flexors, extensors, hip abductors, adductors, ankle plantar and dorsiflexors, forearm pronators, supinators, wrist flexors, extensors, and elbow flexors, extensors.

Strength, endurance, and power testing were accomplished by means of a Cybex II isokinetic dynamometry system coupled with an auxiliary digital work integrator. The Cybex system provides dynamic muscular performance evaluation. It was essential in quantifying these parameters in the fencing profile.

All data tabulations and statistical analyses were performed by a linked series of IBM 370 computers, utilizing the Statistical Pack for the Social Sciences[2] statistical program package.

Once compiled, the data values for all tested parameters were used to construct "musculoskeletal profiles" for the subject population as a whole, and for each individual weapon group. It should be noted that these profiles were derived from a subset of the total raw data. Relationships between

* Presented at the American Academy of Orthopaedic Surgeons, Las Vegas, Nevada, February 2, 1977.

musculoskeletal trauma, and the resultant chronic muscular weakness or contracture have been documented,[3, 4] even in consistently active individuals. Therefore, if a fencer reported any prior injury severe enough to prohibit, even temporarily, actual sports participation, all data from the involved body segment and adjacent segments were excluded from the final profile data, regardless of how much time had passed since the injury had occurred. The same process was applied to any condition or complaint reported by the subjects at the time of testing. This screening reduced the quantity of raw data by approximately 25%. The remaining 75% was judged to represent accurately the normal range of physical characteristics and performance capabilities of fencers at this competitive level, and was therefore utilized in constructing the musculoskeletal profiles.

Statistically, the profile consisted of a frequency distribution, mean, and SD for each of the 239 profile parameters. Of that total, only 86 represented *basic* raw data from the testing protocol. The remaining 153 were *computed* parameters, having been calculated from the raw data. Some examples of the computed parameters are as follows: (1) the ratio of strength, endurance, or power between dominant and nondominant extremities for a given muscle group or reciprocal muscle group pair; (2) the ratio of strength between agonist-antagonist muscle groups about a joint; (3) the ratio of limb segment circumference between dominant and nondominant extremities; and (4) strength or power output adjusted for limb length and/or body weight.

RESULTS

The focus of this paper is upon the methods and implications of sport profiling studies, rather than on the actual data generated by such work. The fencer's musculoskeletal profile will therefore be fully presented in a subsequent publication. There are, however, some general points of significance that warrant mentioning prior to the discussion of the practical value of sport profiles.

Fencers were found to have the most consistently unique profile of all athletes for whom we have only parallel profile data, such as football, basketball, soccer, and hockey players. This was largely attributable to a general asymmetry of muscular characteristics, especially notable in the lower extremities. The asymmetry seen in the lower body of other athletes is typically less marked or nonexistent.

Despite the small sample ($n = 8$) of subjects in each weapon category, 10 statistically significant ($P < 0.05$) differences were found between the profiles of the 3 weapon subgroups. This is an example of the degree of specificity that can exist in athletes' profiles.

Over-all, the fencers were one of the most flexible groups of athletes that we have studied. In marked contrast to their typically asymmetric size, strength, endurance, and power output, their flexibility was generally quite symmetrical.

Although the upper body strength of fencers was found to be unremarkable, the performance capabilities of their lower body musculature were outstanding. Despite a 26 kg average difference in body weight, the swordsmen were very nearly equal to the 1976 New York Jets football squad in over-all leg strength. Their muscular endurance was significantly superior to that of the football players. One épée fencer of 82 kg had greater leg strength and power output than any member of the football squad.

Multiple regression analysis was used to determine whether any of the profile data possessed a predictive relationship with the fencers' actual sport performance. Other investigators[5, 6] have attempted to correlate speed of movement, reaction time, and motor accuracy with success in a single fencing competition. No significant relationships were reported. In this study, a 2-year accumulation of competitively earned national team points was used as the quantitative measure of success. The profile categories of flexibility, strength, and power, each had one parameter that exhibited a significant ($P < 0.05$) simple correlation with the point total. Several highly significant ($P < 0.02$) multiple regression equations were derived from various combinations of these variables. It is our opinion, however, that such predictive formulas must be tested through prospective studies before their validity is fully accepted.

DISCUSSION

Pilot studies done at the Institute of Sports Medicine and Athletic Trauma repeatedly indicated that there were many characteristics and quantifiable musculoskeletal differences between athletes of different sports. Furthermore, this was often true of athletes playing different positions within a given sport. These findings are consistent with the data reported by other investigators whose studies dealt with musculoskeletal,[7-9] cardiorespiratory,[8-10] and psychometric[11, 12] parameters.

The concept of sport-specific profiling is certainly not new. It comes into play every time a physician makes a clinical judgment that is influenced by the type of athlete with which he is dealing. Regardless of the variable under consideration, the physician who knows what to expect from the athlete of a particular sport in the normal, fully functioning state will be more capable of recognizing and defining any abnormalities that may exist when that athlete presents as a patient. Sport profiling data have significant face value because they document the normal range of characteristics for a specific group of athletes.

The profile derived from this prototype study has been successfully utilized as a comparative standard or norm in the orthopaedic evaluation of U. S. national team fencers. Selected musculoskeletal profiling tests were considered to be an important part of each clinical work-up, especially for chronic and/or incompletely rehabilitated injuries. When deviations from the profile mean were observed, objective probability-based criteria were applied to determine their significance. Any test result that was not within 1 SD of the profile mean was considered suspicious, and if not within 2 standard deviations, it was considered abnormal. The previously mentioned *computed* profile parameters were generally found to be more sensitive indicators of an individual's musculoskeletal status than the basic profile parameters. This was due to the high variance typically exhibited by the latter. The analysis would reach the orthopaedist in the form of a report not unlike a musculoskeletal version of the SMA 12 blood test chart. This would then assist the physician in evaluating the athlete's physical status and in recommending the appropriate rehabilitative exercises.

When testing was used for general team screening, profile analysis often revealed significant deficiencies in an actively competing athlete. Frequently, the fencer was not even aware of a problem. Such cases were almost always related to a prior injury. The athlete had typically returned to competition before he was fully rehabilitated and merely avoided or guarded those actions which were compromised. Some of these compensations eventually became a part of his "normal" technique, in spite of the fact that they detracted from his performance. Rehabilitation guidance and attention to form have been used successfully in such cases.

At present, the parallel profiling data we have gathered on high-level competitors from different sports clearly show that each type of athlete represents a unique musculoskeletal profile, no two being the same. Even though certain groups of sports may have many characteristics in common, using the profile of one sport as a standard for athletes of another sport will eventually lead to misinterpretation of their musculoskeletal status. A corollary to this is that the profile of the normal, athletically nonspecialized individual cannot be successfully applied to regular sport participants. A characteristic that is perfectly normal for an athlete might be conspicuously abnormal for the average patient. A classic example of this was the frequent initial misinterpretation of many athletes' low-resting heart rate before this phenomenon became common knowledge. Flexibility, body composition, degree of asymmetry in muscular size or strength, etc., are all subject to this principle of specificity.

Sport profiling techniques are currently being adopted by the Institute of Sports Medicine and Athletic Trauma for a variety of purposes, including pre- and postseason team screening, orthopaedic evaluation, and the determination of sport-specific return to play criteria and rehabilitation programs.

The face value of sport profiling data has been emphasized thus far, but there is considerable knowledge to be gained by studying the developmental aspects of an Olympian profile. The qualities found in such a profile represent both inherent and acquired characteristics. The rise to world class stature involves the selection of favorable, inherent performance qualities, and an extreme degree of physical adaptation to training and sport performance demands.

To discriminate completely between inherent and acquired characteristics, profiling must be done initially in a prospective manner prior to active sport participation, and then again subsequent to the achievement of nationally competitive or Olympic status. Such studies pose formidable difficulties, but the results would have great value. Knowledge of the inherent traits that favor exceptional performance might permit the prospective identification of world class potential in athletes at early stages of sport participation. The determination of the acquired characteristics of an Olympian profile would reveal physical sport performance demands, which might not have been apparent through either observation or participation. It is likely that this could lead to increased sophistication of training methods. These areas

have been focal points of sports performance research in those countries that have become Olympic powers.

A retrospective profiling study such as the one described in this paper can also be used for selection and training purposes, although in a more limited fashion. Statistical analysis may positively or negatively correlate certain profile characteristics with the performance ranking within a given high-proficiency group. Athletes at lower competitive levels could be tested and screened for the favorable qualities identified in this process. If developing athletes are told that they have certain traits in common with the best competitors in their sport, this alone might encourage them to make the sacrifices involved in advancing themselves toward international competition.

With respect to training methods, those individuals striving to achieve Olympic caliber could be tested and then given specific training exercises designed to bring them up to the physical performance test profile of world class competitors wherever their test results fell short of such capabilities.

SUMMARY

A musculoskeletal profiling study was done on 24 members of the U. S. Pan American and Olympic fencing squads. This was presented as a methodological prototype for future, more comprehensive sport profiling studies.

It is proposed that sport-specific profiling data have practical application in the following areas:

1. The identification of physical deficiencies in an athlete, using his or her sport profile as a comparative standard. This would apply to general pre- and postseason screening as well as to medical complaint-related examinations.

2. Providing objective, sport-specific criteria for determining when an injured athlete has recovered to the extent that he or she is adequately prepared to return to play. Rehabilitation goals for full recovery can also be defined.

3. Increasing the efficacy and efficiency of training techniques.

4. The prospective identification of superior performance potential in athletes at early competitive levels.

If sport profiles were developed for the major participant sports at several competitive levels, the profiling system as described here could have significant application to a large number of athletes in a variety of playing situations.

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