A VISIT TO THE SHRINES OF THE VERTICAL JUMP AND THE 40 YARD DASH

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Biomechanics has a unique focus in the study of sports. While other sports subdisciplines such as motor learning, exercise physiology, and sports psychology grapple with hypotheses and theories, biomechanics is in the enviable position of being rooted upon a well defined body of principles and laws. These have been passed on to us by some of the founding fathers of science itself. Included in their number are the disciples Aristotle, da Vinci, Borelli, Galileo, and Newton. Working with knowns and invariability makes it easy for the biomechanist to generalize. If the variables of the equation are known, then the outcome is certainly known. However, such a distilled view of human movement is not possible in the real world. The biomechanist must learn to cope with the inherent variability of human motor performance. This paper will discuss some of the problems encountered in making this transition. Specifically, misinformation regarding two increasingly used predictors of motor ability - the vertical jump and the 40 yard dash - will be explored. It would not be too much of an exaggeration to suggest that these two performances have become shrines of sort , worshipped by those who seek athletic deliverance. But, beware of false gods!

The vertical jump has been of interest to researchers, coaches, and athletes since D.A. Sargent (1921) promoted the notion that the vertical jump could be used as a measure of power in predicting athletic ability. The 40 yard dash has been of particular significance to the players and coaches of American football where it has been used as a measure of innate speed in predicting general athletic ability. Its use has also been extended to other sports and activities. Even the U.S. Department of Energy includes a 40 yard dash from a prone position in its test battery to evaluate the physical fitness of security guards (Telfasir, Atteborn, and Blackwell, 1982). In recent years, a description of the physical characteristics of athletes is viewed as incomplete if their vertical jump height and their 40 yard dash time are not noted. (Witness the vertical jump heights and 40 yard dash times of athletic notables such as William "Refrigerator" Perry, Karch Kiraly, Rita Crockett, and Spud Webb.)

How does biomechanics relate to these performances? If one understands the mechanics of one vertical jump does he also understand the mechanics of another? In other words is the vertical jump in basketball the same as the vertical jump in volleyball or the vertical jump measured using the Vertec?

When the biomechanist investigates the vertical jump does he learn anything about jumping in general or does he only obtain information about a specific jumping pattern? Can his findings be transferred to other forms of jumping?

From the biomechanics view, there is a tendency to treat the vertical jump and the 40 yard dash as general movement patterns. On the other hand, the motor learning perspective is to view these activities as being relatively specific. This perspective is not new. It has been a well established tenet for over 25 years. Franklin M. Henry and his students at the University of California, Berkeley had appeared to settle the question of whether motor abilities are general or specific in nature in the late 1950's and early 1960's. They amassed a formidable amount of evidence through their own studies and by reevaluation of work by earlier researchers, which extended back into the 1920's, that supported the specificity hypothesis. However, coaches, athletes, and sports biomechanists appear reluctant to abandon generality in favor of specificity.

The basic tool employed to evaluate the generality or specificity of motor performance is the correlation coefficient. The correlation coefficient provides information about the strength of the relationship between two variables. However, "The degree of association is not ordinarily interpretable in direct proportion to the magnitude of the coefficient."(Minium, 1970). A meaningful and useful value may be obtained by squaring the coefficient and converting it to percent (i.e. multiply by 100). This is the percentage of variance that is explained or common to the two variables (r^2 or the coefficient of determination). The lack of relationship between two variables is expressed by the coefficient of alienation (k^2). Thus:

$$k^2 = 1 - r^2 \quad \text{and} \quad k^2 + r^2 = 1.00$$

Converting k^2 to a percentage provides a measure of the amount of unexplained or specific variance between the variables. Thus the correlation coefficent can be used to assess the relative amount of generality or specificity in various motor performances (Fig. 1).

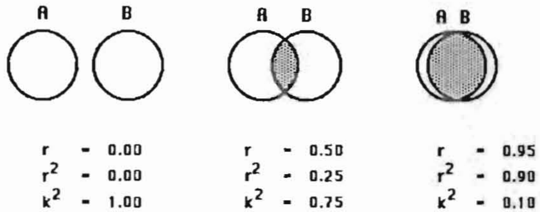

Figure 1. Common and specific variance in the performance of tasks A and B.

In 1958, on the basis of evidence presented by Cozens (1929), Seashore, Buxton and McCollom (1940), Rarick (1937), and Cumbee (1954,1957), Henry concluded that "...it is no longer possible to justify the concept of unitary abilities such as strength, endurance, coordination and agility, since the evidence shows that these abilities are specific to a particular task or activity." (Henry, 1958). The implication is that the performance of an individual in one skill will provide little if any indication of his performance in a second skill. Data from E.A. Fleishman (1964) illustrates this point (Table 1). Of the total performance variance expressed in this table 92 percent is task specific and only 8 percent common. One can conclude that there are probably as many balance abilities as there are balance tasks. Certainly there is very little general balance ability. It is a serious pitfall then to describe an athlete as having good balance. His dynamic balance in a particular skill is probably only slightly related to his static balance in another skill. Indeed, according to Fleishman, the percentage of commonality between a two legged balance on a beam lengthwise and the same balance crosswise is only 3.24%.

It is common to speak of general strength, or upper body strength, or arm strength. L.E. Smith (1968) asked whether strength of the same muscle at the same joint, but at different angles, was general or specific. He measured forearm flexion strength at three different angles

TABLE 1

INTERCORRELATIONS AMONG BALANCE PERFORMANCES

	2	3	4	5	6	7	8
1. 1 Ft. Length Bal. Eyes Op.	.16	.47	.23	.27	.06	.24	.14
2. 1 Ft. Length Bal. Eyes Cl.		.13	.46	.29	.44	.21	.13
3. 1 Ft. Cross Bal. Eyes Op.			.34	.47	.32	.23	.08
4. 1 Ft. Cross Bal. Eyes Cl.				.24	.28	.32	.17
5. 2 Ft. Cross Bal. Eyes Op.					.47	.18	.04
6. 2 Ft. Cross Bal. Eyes Cl.						.11	.06
7. 2 Ft. Length Bal. Eyes Op.							.30
8. 2 Ft. Length Bal. Eyes Cl.							

and at two locations on the forearm. Of the 15 intercorrelations he examined, 12 had 50% or less common variance, indicating greater specificity, and only 3 had common variance greater than 50% (a range of 53% to 59%). Thus it appears that even in very similar strength tasks the inexplicable trend is toward recognizing specificity of performance. Can one then speak of a general attribute of strength when the tasks are dissimilar? Can one even speak of upper arm strength or lower arm strength? The answer is a resounding, No!

What does it mean when it is reported that volleyball player Karch Kiraly has a vertical jump of 41.5 inches, or that Rita Crockett of the same sport can leap 39 inches or that 5ft 9in Spud Webb won the NBA dunking competition, or even that the "Refrigerator" can make it to the top of a MacDonald's table in a single bound? There is no question that these athletes all possess an ability to jump. Rather the question is, as has been repeatedly alleged, do these athletes display a general attribute called power? The question of power and the vertical jump has most recently been examined by Barham, Shetty, and Spooner (1985). They compared Lightsey's Leg Power Formula (Lightsey, 1985) to jump and reach scores and to power scores obtained from a force platform. The correlations were -0.02 and -0.139 respectively. It appears that the type of power reflected in these three performances is highly specific and precludes the conclusion that the vertical jump measures leg power, explosive power, or general power.

Aside from the power issue, can the vertical jump be used to predict high jumping ability, long jumping ability, triple jump ability, basketball jumping ability, volleyball jumping ability, or any other jumping ability? Not very effectively. Let's examine the movement pattern of these jumps. The vertical jump is perfomed with a two foot take off; three of these jumps utilize a one foot take off. The vertical jump is performed from a stationary position; the performer is generally moving in all of the others. Biomechanically, then, there are significant differences in the various movement patterns of these jumps, and because of these differences, they are highly specific neuromuscular tasks. Compounding the problem is the finding that the vertical jump exhibits a learning curve with repeated trials. The best of three trials which is typically used for measurement may be less a reflection of jumping ability than it is of the level of learning on this particular skill. Further, vertical jump performance has been found to be sensitive to short periods of warm-up exercise, and to muscle stretching and massage. It doesn't seem reasonable to even <u>suspect</u> that the vertical jump is a useful tool in predicting other sports performance and the evidence <u>confirms</u> it.

Speed is another trait which is highly prized by coaches and athletes. In a recent article in a widely read journal, Klinzing (1984) stated,

> "The close play at first base, the pass just out of reach, the fast break stopped by a defender rushing back and overtaking a slower dribbler, and the tennis ball that

can't quite be reached are all affected by an athlete's speed. Speed is vitally important to success in most sports. Coaches are making a mistake if they don't teach all of their athletes to sprint faster. If athletes with so-called 'average speed' could improve their speed, they would increase their liklihood for success in almost all sports. Basketball, football, soccer, tennis and many other sports all require quickness and fast running speed in order to excel."

This statement typifies the view of the sports world and explains why there exists a great interest in the trait called speed.

The limitations related to the vertical jump also apply here. Biomechanically, 40 yard dashes in a straight line have very little pattern relationship to what occurs in most actual sports contests. What percentage of football plays result in any of the 22 players running in a straight line for 40 yards? Pity the volleyball, basketball, and tennis players - they don't have a 40 yd straight away on which to run. Other than short sprints in track competition, the patterns of movement that make up the various running speed tasks are significantly dissimilar to the 40 yard dash. Perhaps the most telling evidence regarding the specificity of running speed are correlations among speeds at various distances. For example, Fleishman (1964) found that the correlation between the 10 yard dash and the 50 yard dash was 0.69 indicating that less than half of the variance between these nearly identically appearing tasks was in common. The conclusion is obvious - speed is a specific attribute.

None-the-less the faithful keep trying to use the vertical jump and the 40 yard dash in the real world of sport. Table 2 shows the skills that were used to assess and predict playing ability of members of a professional football team. Table 3 shows the correlations between the rankings of a group of experts (football coaches) and selected test items in recently collected data (Ostarello, 1985). (The coaches ranked the players on the basis of their general football playing ability.) Note that the correlations are generally low and that squaring them would yield very low predictions of various items with playing ability as determined by the coaches. In fact, the percent of commonality between the experts' rank and the nine tests combined was only 20% which leaves 80% specific to the tests. The one anomaly is the Experts' Rank vs the 40 yard dash. This high correlation probably reflects the importance placed upon the 40 yard dash by football coaches. These players were well known to the coaches and had certainly been timed before. The fact that the correlation was not equal to 1.00 might be attributed to a lapse of memory on the part of the coaches.

TABLE 2

TEST BATTERY USED TO ASSESS FOOTBALL PLAYING ABILITY
OAKLAND INUADERS PROFESSIONAL FOOTBALL TEAM

Power	Vertical Jump
Speed	40 Yard Dash
Explosive Start	10 Yard Dash
Cardiovascular Endurance	Treadmill
Upper Body Strength	Bench Press
Upper Leg Strength	Hip Sled
Upper Body Strength and Endurance	Dips
Agility and Coordination	Cone Drill
Leg and Abdominal Strength	Horizontal Jump

TABLE 3

SPEARMAN RANK ORDER CORRELATION FOR SELECTED VARIABLES COMPARED WITH EXPERTS' RANK
(N = 14)

Experts' Rank vs. 40 Yard Dash	=	0.80
Experts' Rank vs. Vertical Jump	=	0.41
Experts' Rank vs. Horizontal Jump	=	0.33
Experts' Rank vs. Bench Press	=	0.05
Experts' Rank vs. Combined Tests	=	0.45

Table 4 shows the correlations between selected variables. One might expect the correlation between the 40 yard dash and the 10 yard dash to be high yet the amount of explained variance is only 34% indicating that these two skills are more different than they are the same. A similar situation holds for the other variables except that the amount of specificity is even higher.

TABLE 4

SPEARMAN RANK ORDER CORRELATIONS BETWEEN SELECTED VARIABLES
(N = 14)

40 Yard Dash vs. Vertical Jump	=	0.57
40 Yard Dash vs. Bench Press	=	0.07
40 Yard Dash vs. 10 Yard Dash	=	0.58
Vertical Jump vs. Bench Press	=	0.27

Some interesting information on the 40 yard dash, the vertical jump and power was presented by McCardle, Katch, and Katch (1986) (Table 5). They examined the relationship between four tests of power. They suggested that if various power tests measure the same metabolic capacity, then individuals who do well on one test should also do well on others. The table shows that the correlations are moderate at best. With one exception, the indication is that even with tests that are supposed to measure the same trait, human performance is highly task specific. The high correlation between the 40 yard dash and the Margaria power test is of particular interest. The correlation suggests that coaches should abandon the 40 yard dash as a measure of speed and adopt it as an assessment of power as measured by the Margaria power test. Or perhaps we should be very skeptical of both of these tests because the general attribute they purport to measure does not exist.

TABLE 5

CORRELATIONS AMONG TESTS THAT ARE SUPPOSED TO MEASURE IMMEDIATE ANAEROBIC POWER OUTPUT

VARIABLES (N = 31 males)	40 YARD DASH	SARGENT JUMP TEST	POWER BICYCLE TEST
1. Margaria Power Test	- 0.88	0.56	0.69
2. 40 Yard Dash	---	- 0.48	-0.62
3. Sargent Jump Test	---	---	0.31

What does specificity data indicate for the world of sports biomechanics? First, biomechancal generalization regarding athletic performance should be approached with caution as analysis of the dynamics of one pattern does not necessarily apply to other apparently similar tasks. There is ample value in understanding the biomechanics of specific skills; to simplistically categorize performance into common patterns when none exists is unwarranted. Secondly, one must be extremely wary when using or devising teaching and training simulators. This last point warrants some expansion in view of the interest which has been ellicited recently. The principle of specificity would predict little success for such devices in general because of the near impossibility of precisely duplicating the actual performance with a simulator; a general similarity is not enough. "The best practice task is the task itself," may well be the golden rule. The pitfalls in the use of simulators may be illustrated by the efforts in cross country skiing.

Cross country skiers have long used roller-skiing as a training modality in the off season. What are the advantages of such training? The advantages according to cross country ski coach John Caldwell (1979) are:

1. Best form of specificiy training for cross country skiing.
2. Stressing uphill training will develop a stronger stride than uphill snow skiing.
3. Will prepare muscles for on-snow skiing
4. Video and film will allow analysis of snow skiing technique.

The disadvantages include:

1. Relatively easy to cross skis.
2. Roller skis don't maneuver well - Avoid turns.
3. Long downhill can be too fast for safety.
4. Ratcheted wheels can result in degradation of technique if uphill training is too vigorous.

Although Caldwell's efforts are in the right direction, his list of disadvantages casts doubt on the similarities of the two tasks. If roller-skis and roller-skiers performed on wheels as they did on snow, then the skis would be no less likely to cross on land than snow; the skis would manuever equally well in both situations, and there would be no changes in technique in vigorous uphill training. It is apparent that roller skiing and snow skiing are specific tasks.

Another example may be found in the sport of flatwater canoeing. Holt and Campagna (1985) clearly illucidated the specificity issue when they compared the biomechanical and physiological parameters of flatwater canoeing with the Pyke Ergometer - a flatwater canoeing simulator. They found that although the oxygen cost for the 500 meter event was very similar to that of the ergometer exercise, the movement patterns were different. This is exactly as specificity would predict. Metabolic requirements for a given work load could be the same while the activity differs markedly.

It seems that roller-skiing, cross country skiing, ergometer training, flatwater canoeing, vertical jumps, and 40 yard dashes are all different. The ability to perform these tasks will not to any great extent predict one's ability to perform others. Clearly, from the standpoint of efficiency it is better to design training programs that are as similar as possible to the actual conditions under which the athlete will perform - preferably identical. It should be recognized that many factors, e.g. motivation, variety, boredom, which have little to do with neuromuscular specificity or biomechanics may play an important, perhaps even a dominant role, in an athlete's performance. Awareness of these types of influences can ultimately influence the biomechanist's perspective.

The field of sports biomechanics has not, in general, been apprised of developments in allied fields. To focus only on biomechanics without regard to these other disciplines is myopic and can only lead to incomplete understanding of the real problems.

Finally, as we continue the quest for performance improvements through sport biomechanics let us not forget the nomadic Masai tribe of eastern Africa (Hollis, 1905). In an effort to appear larger and more fearsome to their enemies, they are reported to jump "almost their own height" without the help of force platforms, high speed cinematography, or computer analysis.

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