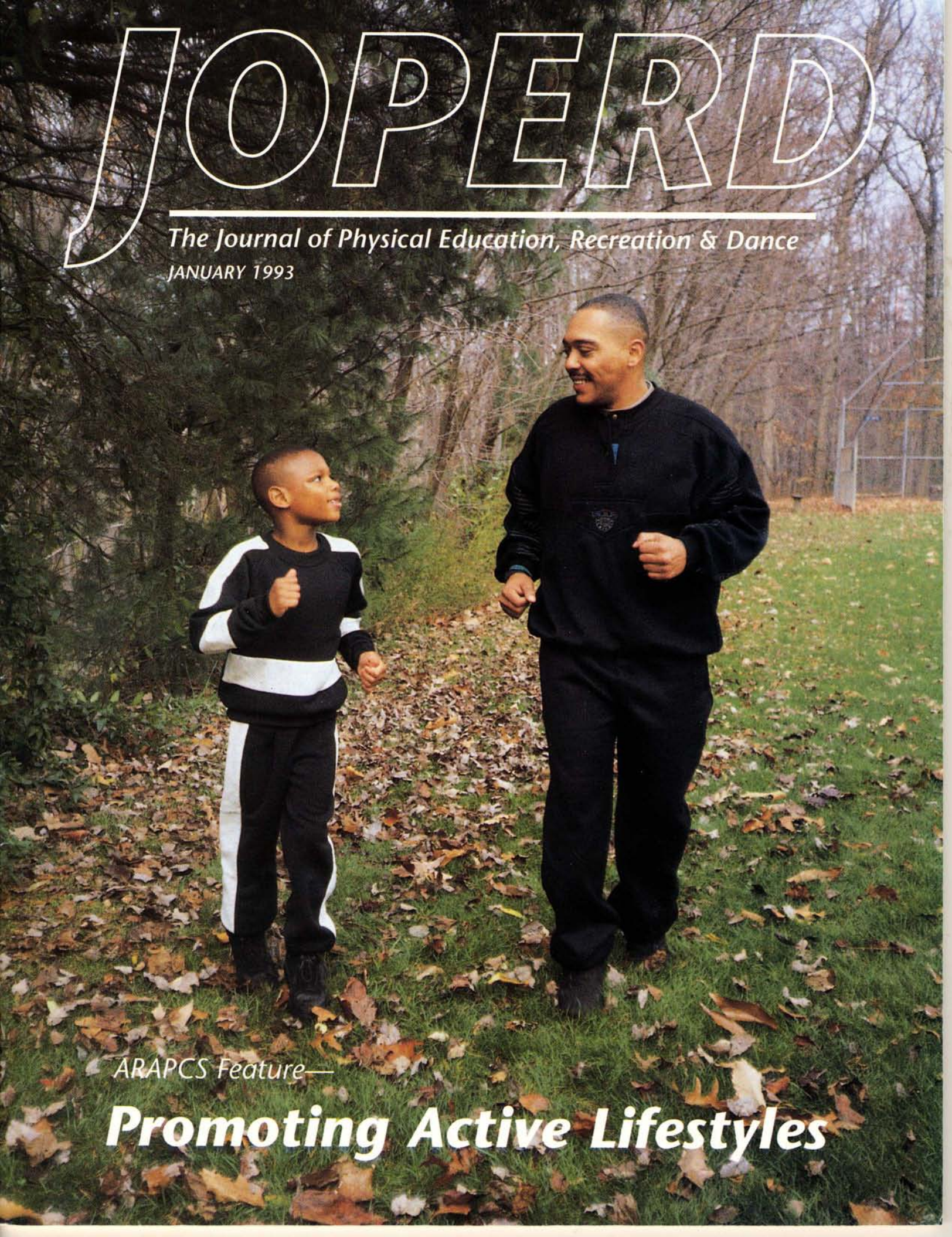

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ARAPCS Feature—

Promoting Active Lifestyles

Strength Testing—
Predicting a One-Rep Max from Reps-to-Fatigue

Obtaining a one-rep max offers a safe, practical, and reasonably accurate means of qualifying the muscular strength of large numbers of people in an inexpensive, convenient, and time-efficient manner.

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Prior to 1880 in America, tests in the physical domain focused primarily on anthropometric measurements such as muscle size and body symmetry. Throughout the next 30 years, the trend in measurements shifted toward muscular strength testing—mostly through the efforts of Dudley A. Sargent, an assistant professor of Physical Training at Harvard. In its infancy, early strength testing was unscientific and based on empiricism. However, strength testing experienced a resurgence in the 1920s. This resurrected interest led to the development of new, more scientific tests, along with the availability of new statistical techniques for data analysis.

Since then, strength testing has gradually become much more sophisticated. Essentially, two types of strength tests have evolved: static and dynamic. Static (or isometric) tests are those in which a muscle exerts tension against a fixed, nonmoving resistance; dynamic (or isotonic) tests involve actual movement of one or more body parts against a resistance.

Strength tests can now be done in a laboratory setting or human performance facility using a variety of equipment ranging from relatively simple dynamometers and tensiometers to much more elaborate isokinetic testing devices. Interfaced with a computer, some equipment can even measure strength over a full range of motion and plot a strength curve with an incredible degree of accuracy and repeatability. Unfortunately, lab testing is not practical for meeting the volume of tests that physical educators, coaches, and athletes request. In addition, laboratory tests can be expensive and time consuming. On the other hand, field tests are simple, convenient, and contain easy-to-administer methods of measurement that require a minimum amount of time, cost, and equipment. As a result, most strength and fitness professionals rely on various field tests to measure strength.

The most popular (and traditional) way to assess dynamic strength has been to determine how much weight an individual can lift for one repetition. Indeed, obtaining a one-repetition maximum (1-RM) is perhaps the most frequently used field test for evaluating muscular strength. Such tests are usually performed using three or four exercises that are representative of the body's major muscle groups. For example, a bench press or an incline press is typically used to assess the strength of the chest, shoulders, and triceps while a squat or a leg press is often used to measure the strength of the hips and legs. However, safety becomes a major concern when the lifter performs with a maximal weight for one repetition. Attempting a 1-RM with heavy weights can place an inordinate and unreasonable amount of stress on the muscles, bones, and connective tissues. An injury occurs when the stress exceeds the tensile strength of the structural components. Additionally, a 1-RM attempt tends to increase blood pressure beyond that which is normally encountered when using submaximal weights. These concerns are magnified when testing certain populations such as adolescents and older adults. Another concern is that a 1-RM lift is a highly specialized skill that requires a great deal of technique. Clearly, strength and fitness professionals must identify a safe and practical—

yet reasonably accurate—means of qualifying the muscular strength of large numbers of people in an inexpensive, convenient, and time-efficient manner.

Anaerobic Endurance

At this point, two terms—"strength" and "anaerobic endurance"—must be distinguished. For the purposes of this discussion, strength can be defined as a person's ability to exert force. Furthermore, a person's maximum strength is a measure of his or her capacity to exert force during a single maximal muscular contraction. Anaerobic endurance relates to a person's ability to perform successive muscular contractions with a heavy, near-maximal load for a relatively short period of time. Anaerobic endurance must not be confused with cardiovascular endurance. Anaerobic endurance is a short-term, high intensity muscular effort—less than about two minutes; cardiovascular endurance involves muscular effort for a much longer duration.

Strength and anaerobic endurance are, in fact, highly related. A review of the strength training literature by Sale and MacDougall (1981) noted the unpublished observations of Anderson and Haring (1977) which indicated that there is a direct relationship between reps-to-fatigue and the percentage of maximal load: as the percentage of maximal weight increased, the number of repetitions decreased in an almost linear fashion. It was also suggested that 10 repetitions can be performed with a weight that was equal to approximately 75 percent of a maximal load. For example, if your 1-RM is 200 pounds then you can perform 10 reps-to-fatigue with 150 pounds (75% of 200). In other words, if your maximal strength is 200 pounds, then a measure of anaerobic endurance is your ability to perform 10 reps with 150 pounds before experiencing muscular exhaustion. Unless there is an injury or other musculoskeletal disorder, the relationship between muscular strength and anaerobic endurance remains constant. So, regardless of whether your strength increases or decreases, you will always be able to perform exactly 10 reps

One person's strength should not be compared to another's.

Table 1. Predicted Max Based on Reps-to-Fatigue

Wt	Repetitions									
	1	2	3	4	5	6	7	8	9	10
45	45	46	48	49	51	52	54	56	58	60
50	50	51	53	55	56	58	60	62	64	67
55	55	57	58	60	62	64	66	68	71	73
60	60	62	64	65	67	70	72	74	77	80
65	65	67	69	71	73	75	78	81	84	87
70	70	72	74	76	79	81	84	87	90	93
75	75	77	79	82	84	87	90	93	96	100
80	80	82	85	87	90	93	96	99	103	107
85	85	87	90	93	96	99	102	106	109	113
90	90	93	95	98	101	105	108	112	116	120
95	95	98	101	104	107	110	114	118	122	127
100	100	103	106	109	112	116	120	124	129	133
105	105	108	111	115	118	122	126	130	135	140
110	110	113	116	120	124	128	132	137	141	147
115	115	118	122	125	129	134	138	143	148	153
120	120	123	127	131	135	139	144	149	154	160
125	125	129	132	136	141	145	150	155	161	167
130	130	134	138	142	146	151	156	161	167	173
135	135	139	143	147	152	157	162	168	174	180
140	140	144	148	153	157	163	168	174	180	187
145	145	149	154	158	163	168	174	180	186	193
150	150	154	159	164	169	174	180	186	193	200
155	155	159	164	169	174	180	186	192	199	207
160	160	165	169	175	180	186	192	199	206	213
165	165	170	175	180	186	192	198	205	212	220
170	170	175	180	185	191	197	204	211	219	227
175	175	180	185	191	197	203	210	217	225	233

Wt	Repetitions									
	1	2	3	4	5	6	7	8	9	10
180	180	185	191	196	202	209	216	223	231	240
185	185	190	196	202	208	215	222	230	238	247
190	190	195	201	207	214	221	228	236	244	253
195	195	201	206	213	219	226	234	242	251	260
200	200	206	212	218	225	232	240	248	257	267
205	205	211	217	224	231	238	246	254	264	273
210	210	216	222	229	236	244	252	261	270	280
215	215	221	228	235	242	250	258	267	276	287
220	220	226	233	240	247	255	264	273	283	293
225	225	231	238	245	253	261	270	279	289	300
230	230	237	244	251	259	267	276	286	296	307
235	235	242	249	256	264	273	282	292	302	313
240	240	247	254	262	270	279	288	298	309	320
245	245	252	259	267	276	285	294	304	315	327
250	250	257	265	273	281	290	300	310	321	333
255	255	262	270	278	287	296	306	317	328	340
260	260	267	275	284	292	302	312	323	334	347
265	265	273	281	289	298	308	318	329	341	353
270	270	278	286	295	304	314	324	335	347	360
275	275	283	291	300	309	319	330	341	354	367
280	280	288	296	305	315	325	336	348	360	373
285	285	293	302	311	321	331	342	354	366	380
290	290	298	307	316	326	337	348	360	373	387
295	295	303	312	322	332	343	354	366	379	393
300	300	309	318	327	337	348	360	372	386	400
305	305	314	323	333	343	354	366	379	392	407
310	310	319	328	338	349	360	372	385	399	413

with about 75 percent of your maximum. Therefore, if you increase your 1-RM to 240 pounds, then you can perform 10 reps-to-fatigue with 180 pounds (75% of 240). Conversely, if your anaerobic endurance is increased, then your muscular stress is also increased. Referring back to the previous example, if you increase your 10-RM by 20 percent (from 150 to 180 pounds) then you will increase your 1-RM by 20 percent (from 200 to 240 pounds).

Implications for Testing

Since there is a distinct relationship between anaerobic endurance and strength, anaerobic endurance can be determined by measuring strength—and strength can also be determined by measuring anaerobic endurance.

Though not a direct measure of pure maximal strength, a test of anaerobic endurance is much safer than a 1-RM lift because it involves submaximal loads. How can anaerobic endurance be assessed? Well, if a person knows—or can find out by trial and error—the most weight he or she can lift using proper form for exactly 10 reps, simply divide the weight lifted by .75. That number will give a rough estimate of predicted 1-RM. For instance, if you can do 10 reps-to-fatigue with 225 pounds when testing your anaerobic endurance, then your predicted 1-RM would be about 300 pounds. But what if a coach wants to evaluate an entire team and does not have the time to retest athletes who will inevitably do either less than or more than 10 reps-to-fatigue? Anderson and Haring (Sale & MacDougall, 1981) noted a near linear relationship between the number of reps-to-fatigue and the percentage of maximum load. The relationship was not exactly linear but close enough to determine a reasonably accurate linear approximation for describing the relationship between the two variables. In fact, based upon their observations, I calculated a mathematical equation for predicting a 1-RM based upon reps-to-fatigue (figure 1).

It appears as if the relationship is not quite linear beyond about 10 reps. Therefore, this formula is only valid for predicting a 1-RM when the number of reps-to-fatigue is less than 10. If the reps exceed about 10, then the test becomes less accurate for evaluating anaerobic endurance as well as for estimating a 1-RM. Table 1 provides a quick and easy reference for predicting a 1-RM based on reps-to-fatigue with weights ranging from 45 to 310 pounds. The numbers used in the table were determined using the equation in figure 1.

$$\text{PREDICTED 1-RM} = \frac{\text{Weight Lifted}}{1.0278 - .0278X}$$

where X = the number of reps performed

Figure 1. Equation for Predicting 1-RM Based on Reps-to-Fatigue

Genetic Influences

It has been suggested that a person will be able to perform 10 reps-to-fatigue with about 75 percent of a maximum load. However, each individual inherits a different potential for increasing various physical attributes such as muscular size, muscular strength, cardiovascular endurance, and anaerobic endurance. A person's physical profile is largely determined by several inherited characteristics such as predominant muscle fiber type, muscle-to-tendon ratio, limb length, and neurological ability. Because of these "genetic influences," some people are able to perform either less than or more than 10 reps-to-fatigue with 75 percent of a maximum load. So if predicting a 1-RM from a test of anaerobic endurance is to be more precise, then individual differences should be considered. How can you determine more specifically how your maximal strength relates to your anaerobic endurance? First of all, to test your maximal dynamic strength, determine how much weight you can lift for one repetition in good form. (This may be the last time that you will ever have to "max out.") To assess your anaerobic endurance, simply take 75 percent of your 1-RM and do as many reps as possible. Suppose that the most weight you can lift for one rep is 280 pounds, but, unlike most individuals, the most reps you can do with 210 pounds (75% of 280) is 8 reps. In this case, to estimate a 1-RM based upon your inherited characteristics, divide the most weight you can lift for 8 reps (instead of 10) by .75. Because genetic traits may differ from one muscle to another, the relationship between anaerobic endurance and muscular strength for each major muscle in the body must be determined for more precise measurements. However, the equation and the numbers used in table 1 will still be accurate for predicting a 1-RM for most of the population.

Perspectives on Testing

The purpose of strength testing should not be to compare the strength of one person to another. It is unfair to make strength comparisons between individuals because each person has a different genetic potential for achieving muscular strength. Strength testing is more meaningful and fair when an individual's performance is compared to his or her last performance—not the performance of others.

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