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Physiological Profiles of Elite Senior Wrestlers

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Abstract

To perform excellently in international competitions, wrestlers have to achieve an excellent level of physical fitness and physical condition during training. This article reviews the physiological profiles of elite wrestlers. In general, successful wrestlers showed higher dynamic and isokinetic strength than unsuccessful wrestlers. In particular, upper body strength and anaerobic power were significantly different between the two groups.

Aerobic capacity is one of the most important physical factors to achieve good results in wrestling competitions. The maximal oxygen uptake of national and international wrestlers taking part in international competition has been shown to be about 53 to 56 ml/kg/min. Around the time of the Seoul Olympics, typical values for wrestlers were about 60 ml/kg/min, with values of >70 ml/kg/min in some cases (the latter being similar to values reported for some endurance runners). The flexibility of the wrestlers was found to be lower than that of weight lifters and gymnasts. However, the flexibility of top-level wrestlers was higher than that of lower level wrestlers. To fully understand the physiological profiles of successful wrestlers, further research regarding anaerobic and aerobic energy metabolism, cardiopulmonary responses, body fat content, and changes in muscle hypertrophy both during the wrestling season and off-season is warranted.

The criteria for winning in wrestling have changed periodically at the international and national level. Currently, the champion of an international bout is decided by either a fall or, if no fall occurs, by a scoring system that quantifies which wrestler is most superior with respect to controlling the opponent. Along with variations in the scoring system the match duration differs among styles and eras.

The time limit of matches has varied from 9 minutes (three 3-minute rounds with a 1-minute rest between rounds) in the 1950s, to 6 minutes (two 3-minute rounds with a 1-minute rest between rounds) in the 1980s, to only 5 minutes in duration without a rest period in the 1990s, and two 3-minute rounds with a 30-second rest between rounds in current international competition.

Modification in the scoring system and match duration may dictate the type of athlete who will be successful in wrestling. Periodic rule changes may also influence the methods of training used by successful wrestlers. Profiles of the physiological capacity of amateur wrestlers have been examined with the intent of identifying attributes that are important for success.

Wrestling is a very vigourous physical activity and sport. It requires tremendous physical preparation as well as significant psychological and emotional preparation. In the last few decades, there has been a great amount of research done in physiology and other fields relating to better performance in wrestling and other sports.

The purpose of this article is to review some of the physiological factors related to successful wrestling training.

1. Physique and Body Composition

Optimal body composition is a concern of the wrestler because competitors are matched by bodyweight and must 'make weight' prior to each meet. The majority of wrestlers attempt to maximise the amount of lean tissue, minimise the amount of body fat, and minimise the total bodyweight.

Once it is recognised that the range of weight categories stretches from 54 to 130kg super heavyweights, the task of isolating a single body type or anthropometric profile seems impossible. Nevertheless, there is some commonality throughout much of the range in terms of characteristic somatotypes and a predominance of mesomorphy.

In terms of physique, the wrestler is generally thought to have a somatotype that accentuates the mesomorphic character (very high muscularity, low linearity, low fat). World champions usually have less than 10% body fat, but they do not subscribe to the detrimental practice of excessive bodyweight changes. If anything, they 'bulk-up' to a higher weight class and are exceedingly strong per kilogram of bodyweight. Ideally, a prospective wrestler should employ sound nutrition and aerobic training principles to reach a steady-state fat percentage of 7 to 10%.[1]

Since wrestlers compete at their weight categories, it is not surprising that they are very strong per kilogram of bodyweight. This means that they must have a very small percentage of body fat compared with an average male of the same height and age. Indeed, the range of fat percentage extends from about 4 to 9%, with the exception of the super heavyweights.

Whether measured in-season (during training and competition) or off-season, most wrestlers are very lean, possibly because of the year-round training and/or their genetic makeup. Off-season values for percentage body fat range from 8 to 16% in the well-trained stage. The percentage body fat of male wrestlers from the Brigham Young University wrestling team is about 13.30% body fat.[2] Wrestlers appear to have between 3 to 13% fat, which is exceptionally lean compared with nonathletes and most other athletes.[3] However, no relationships appear to exist between the level of wrestling success and the percentage of body fat.[4]

In Olympic wrestlers, DeGaray et al.[5] reported very high ratings for the mesomorphic characteristic and low endo- and ectomorphy. DeGaray et al.[5] also found that no difference was observed between Graeco-Roman and freestyle wrestlers for the ratings. Scores for endo- and mesomorphy tended to increase and the ectomorphy ratings tended to decrease in progression from the test wrestlers through the heaviest weight class.

Regarding physique, Olympic wrestlers have high ratings for the mesomorphic characteristics and low endo- and ectomorphic characteristics.[5] Graeco-Roman and freestyle wrestlers together have mean somatotype values of 2.3, 6.4, and 1.6 for endomorphy, mesomorphy, and ectomorphy, respectively. Furthermore, the ratings were not different between the two styles. Endo- and mesomorphy ratings tended to increase and the ectomorphy ratings tended to decrease in progression from the lightest to the Olympic wrestlers.[5]

Current research supports the stereotype of amateur wrestlers having strong mesomorphic characteristics. Despite the observations that successful high school wrestlers compete closer to their minimum bodyweight (i.e. at a lower percentage of body fat) than less successful wrestlers,[6] and that successful high school wrestlers have lower body fat than less successful peers,[7] most studies on collegiate and international-calibre wrestlers in the US showed no differences between the body fatness of successful and less successful wrestlers.

2. Anaerobic Characteristics

2.1 Strength

Strength is the maximum ability to generate force independent of time and distance of movement. It depends upon the ability of the nervous system to recruit motor units, the ability of the muscle to utilise the energy anaerobically [adenosine triphosphate-phosphocreatine (ATP-PC)] for muscle contractions and the amount (cross-sectional area) of muscle fibres present. Because of the relationship to cross-sectional area and size, strength is often analysed relative to bodyweight; the so-called relative strength.

Early studies on wrestlers focused on isometric or static strength. At international levels of competition, rules changed in the 1970s, emphasising aggressive wrestling and scoring rather than holding and blocking the opponent, that is, 'stalling'. Consequently, the dynamic strength of wrestlers (e.g. the force during maximum isokinetic, concentric or eccentric contraction) has received more attention.

Song and Garvie[8] reported that, as expected, absolute strength is greater in heavier wrestlers than in lighter wrestlers; however, the reverse is true for relative strength. When comparing successful with less successful wrestlers or the experienced to the novice, it appears that greater strength is advantageous. The greatest differences were observed in the tests for upper body strength. In contrast, Silva et al.[9] reported no differences in isometric grip strength of the successful and less successful wrestlers contending for the junior world games team. Discrepancies in the findings of these studies[7,9,10] could be caused by the type of competition (scholastic and college *vs* international, i.e. junior world and Olympic).

In adolescent wrestlers, a composite of isokinetic strength measurements distinguished the successful wrestler from the least successful.[7] A similar, although nonsignificant, trend existed for successful collegiate wrestlers possessing greater isokinetic strength, particularly in the upper body, compared with collegiate wrestlers who were not place winners.[10] In contrast, no difference was noted in isometric grip strength between the successful and the less successful wrestlers competing for the junior world games team.[9]

2.2 Anaerobic Power

Power is the amount of work accomplished per unit of time. In wrestling, opponents are matched by size and presumably power. However, it is possible for opponents at the same weight class to differ in relative power. Power in wrestlers is associated with quick, explosive manoeuvres that lead to control of the opponent.[11] The sources of energy for their quick and explosive exertions are the phosphagens (ATP-PC) and glycogen (anaerobic glycolysis). The two most commonly used tests to evaluate the maximum ability of wrestlers to generate power are the Margaria stair climb (test duration ≈1 second) and the Wingate anaerobic test (test duration 30 seconds). Another test of anaerobic capacity is the Wingate test on a bicycle ergometer. An individual pedals the ergometer as fast as possible at a load relative to bodyweight, and the number of revolutions in 30 seconds reflects the anaerobic capacity.

Peak anaerobic power (maximum power in a 5-second interval) and anaerobic capacity (mean power for the 30-second interval) are obtained using the Wingate test. The peak anaerobic power of male wrestlers from the Brigham Young University wrestling team is about 10.78 watt/kg.[2] The anaerobic power of Korean national wrestlers (table I) is similar to that of wrestlers at the international level. Data on Korean national wrestlers were ob-

Table I. Summary of anaerobic power data from Korean national wrestlers (n = 8)[12]

	Total work (30 sec: kpm/kg)	Peak power (W/kg)	Mean power (W/kg)	Fatigue index (%)
Mean	1350.0	11.2	6.7	46.5
Standard deviation	311.2	1.8	1.0	9.3

tained from the Wingate test (unpublished observations).

Compared with other athletes, wrestlers' anaerobic performances are more similar to those of power athletes than endurance athletes on the basis of equivalent bodyweight (W/kg). Anaerobic power may help to differentiate between successful and less successful wrestlers. The anaerobic power and capacities of elite junior wrestlers are increased by as much as 13% compared with non-elite wrestlers of similar bodyweight, age and wrestling experience. This may be due to differences in the relative amount of muscle[13] or possibly differences in neuromuscular recruitment.

Anaerobic power is closely related to the different composition of skeletal muscle.[14] It was estimated that senior wrestlers on the Swedish national team averaged ≈56% fast twitch fibres for lower body muscles (gastrocnemius or vastus lateralis). Wrestlers appeared to have the greatest variability in the percentage of slow twitch fibres among the trained athletes; however, the sample size was small (n = 5).[14] In another study,[15] eight Swedish senior wrestlers had a mean of 53% fast twitch fibres in the lower body (vastus lateralis). In comparison, the upper body muscle (deltoid) of the same wrestlers was lower with regard to fast twitch fibres at 39%.

Sharratt et al.,[16] also sampled the vastus lateralis, and reported that for 21 Canadian freestyle wrestlers the average percentage of fast twitch fibres was 53%. Interestingly, the authors of that study observed that the cross-sectional area of the fast twitch fibres was larger than that of other athletes. However, Taylor et al.[17] suggested that cross-sectional area is related to the size of the wrestler.

The new demands concerning the effectiveness of combat actions that are prompted by the new international competitive rules require, as far as condition goes, a more accurate assessment of the capacity of power endurance. Power endurance is primarily expressed in the competitive power output of an individual action or sequence of actions (e.g. a spurt with several individual actions).

The roll-over simulator, for example, allows one to simulate the strength demands that are required for executing the roll-over. Thus, technique-related strength training becomes objective with regard to its effects, and the athlete receives biofeedback to become aware of his/her own special strength capacity.

2.3 Lactate Level

The general physiological characteristics of an elite senior wrestler are high anaerobic power and capacity, and high muscular endurance in an anaerobic energy system.

Observation of the intensity of wrestling reveals that the anaerobic component is of vital concern. Indeed, the blood lactate concentration in wrestlers has been recently used as an indicator of anaerobic power and capacity in successful wrestlers.

A laboratory study[12] in Korea investigated lactic acid levels during a computerised bicycle ergometer test and two exhaustive running tests on a treadmill. The wrestlers had blood samples taken immediately following the ergometer and treadmill exercises. Lactate levels in venous blood increased about 10-fold after the exhaustive exercises.

When evaluating well-trained wrestlers for 5 minutes in actual competition, venous lactate concentrations were about 10 to 13 mmol/L in elite Korean wrestlers.[18] However, Sharratt et al.[16] reported that the best Russian wrestler generated over 20 mmol/L, which was much higher than values for Canadian or US wrestlers, with lactate levels of 10 to 15 mmol/L following similar anaerobic exercise (unpublished observations).

In terms of biochemistry, the capacity of muscle to maintain maximum power for this duration of time is thought to be due to its capacity to undergo anaerobic glycolysis, buffer metabolic acids, and aerobically metabolise fuel for energy. Generally, because extremely higher intensity-trained athletes are less sensitive to lactic acid and better able to tolerate higher levels than average athletes, it is possible that they also learn to withstand and even ignore the pain threshold, which is surpassed with high lactic acid levels. For example, successful wrestlers may be more tolerant of lactate (lactate tolerance) as well as more capable of blood buffering for muscular endurance.[20]

Consequently, another area for future research is that of optimal training for wrestlers. This issue needs to be examined more carefully in training methods such as continuous versus interval or overtraining.

2.4 Muscular Endurance

Muscular endurance is the ability to sustain muscular performance at a high intensity, that is, at or near 100% of maximum force or power, for more than 30 seconds, but <2 minutes. Unfortunately, there is no universally accepted method of evaluating these capacities relative to physical performance. A variety of tests have been used in wrestlers as well as other athletes, making comparisons somewhat difficult. Muscular endurance has been evaluated by different protocols such as bench press repetitions, 2-minute work of intermittent arm cranking, two runs to exhaustion on a treadmill, and the Cybex test. In a study using a different protocol, Canadian freestyle wrestlers performed two runs to exhaustion on a treadmill.[21] The runs, which were separated by 4 minutes of rest, were made at a speed of 12.8 km/h (8 miles/hour) with an incline of 20% grade. Wrestlers stayed on the treadmill for an average of 56 and 45 seconds for the first and second run, respectively. Treadmill times and blood lactate concentrations, which averaged 14.0 mmol/L at the end of the second run, were comparable with those of athletes in other anaerobic sports.[21] Future research on wrestling is likely to focus on the mechanism by which dynamic endurance is related to success in the sport and the mechanism by which dynamic endurance is improved. Enzyme activity levels for phosphofructokinase in the vastus lateralis muscle from Canadian freestyle wrestlers were similar to those of other anaerobically-trained wrestlers (34.5 mol/g wet weight muscle/min).[21] However, other factors such as the buffering capacity of the muscle and blood need to be investigated to determine how wrestlers may differ from other athletes, and how successful wrestlers differ from the less successful wrestlers.

Table II. Summary of results from the test for reaction time for the Korean national wrestling team (n = 24)[22]

Classification	Average	H-score	L-score
Reaction time (m/sec)	512	612	364
Movement time (m/sec)	1986	2196	1572
Force (g/msec)	5162	6776	4231

H-score = highest score; **L-score** = lowest score.

2.5 Reaction Time and Quickness

Reaction time, or the speed at which a person moves in response to a stimulus, is a critical element in most sports. Recently, a series of tests for reaction time have been developed specifically for wrestling; the tests not only measure the speed of movement in reaction to the stimulus but also account for the technical ability with which the movement is completed.[17] To date, the series of tests has not been used to compare reaction times of successful and less successful wrestlers but such information could be very useful in profiling champion wrestlers. This information can be acquired using software (KCK system) in our laboratory. This system consists of a computer, sensor and interface. For example, using the KCK system, 24 wrestlers from the Korean national wrestling team were tested (table II). With these results, investigators can find out how the wrestlers achieved the score and who had the best or lowest rating. This information provides important information regarding how the training programme should be organised.

3. Aerobic Characteristics

3.1 Cardiovascular

Maximal oxygen uptake ($\dot{V}O_{2max}$) is the volume of oxygen that can be utilised per minute to perform work. It has been reported that the $\dot{V}O_{2max}$ of national and international wrestlers is about 53 to 56 ml/kg/min, which is not exceptional for any well-trained athlete (table III). The $\dot{V}O_{2max}$ of male wres-

Table III. Summary of peak oxygen uptake (ml/kg/min) data

Reference	Level	Treadmill	Arm crank	Cycling
Clark et al.[23]	23 wrestlers	51.5		
	22 controls	48.0		
Seals and Mullin[24]	10 collegiate	62.4	40.6	45.4
Horswill et al.[25]	18 high school (adolescent)	53.0	41.0	
Sharratt et al.[16]	Canadian freestyle	61.8		
Song and Garvie[8]	Seniors			
	15 Canadian			54.5
	19 Japanese			55.6
Yoon and Jun[12]	Seniors[a] 21 Korean	60.24		

a Mean age 23 years, mean duration of career 9 years.

tlers from the Brigham Young University wrestling team is about 56.3 ml/kg/min.[2] This range was not high compared with that of elite endurance runners who are measured at 70 to 80 ml/kg/min. Nevertheless, the wrestlers' values were higher than the average of active males of 35 to 45 ml/kg/min. However, it is interesting to note that there was a period during the mid-1980s when aerobic capacity was more highly esteemed. Around the time of the 1988 Seoul Olympics, there was a tendency to recruit wrestlers with maximal aerobic capacities of about 60 ml/kg/min, and some even exceeded 70 ml/kg/min. It appeared that the 6-minute matches demanded this kind of aerobic intensity at the expense of strength and power. The US wrestlers seemed particularly well suited to these demands and were challenging the traditionally powerful countries. The Wrestling Federation reduced the length of the bout from two rounds of 3 minutes to one round of 5 minutes without a rest period. As a result, the orientation of energy delivery systems changed back to an anaerobic focus with good aerobic support.

There was a debate over which was the best aerobic test for wrestlers. Traditionally, a graded treadmill test and a bicycle ergometer test have been used, but these are not specific to wrestlers. Even a combined arm and leg test with two ergometers presents a measurement and standardisation challenge. The modern-day laboratory provides a computer print-out of oxygen uptake ($\dot{V}O_2$), heart rate, ventilation, and anaerobic threshold. Oxygen pulse and ventilatory equivalents can also be calculated from the raw data.

In reviewing studies comparing the peak $\dot{V}O_2$ ($\dot{V}O_{2peak}$) of successful and less successful wrestlers, it appears that $\dot{V}O_2$ is not a major determinant of success. Stine et al.[10] and Horswill et al.[13] showed that at three levels (Olympic, collegiate and scholastic), the $\dot{V}O_{2peak}$ was not significantly different between successful and less successful counterparts. Specifically, freestyle wrestlers[21] seemed to have a higher $\dot{V}O_{2peak}$ than Graeco-Roman competitors.[17,26] It is not known whether a difference truly exists or a higher $\dot{V}O_{2peak}$ is more important in freestyle than Graeco-Roman competition.

Through the 1980s, the match duration in world-level competitions was 6 minutes (two 3-minute periods separated by a 1-minute rest period). Currently, matches are 5 minutes in duration without a rest period. Therefore, as Sharratt[27] observed, it is possible that aerobic power and cardiovascular endurance are not as critical for match success as previously suggested. Unfortunately, there is not enough data available to determine whether $\dot{V}O_{2peak}$ values of current elite international wrestlers have decreased relative to shortened the match duration.

3.2 Pulmonary

With a few exceptions, research on the pulmonary systems of wrestlers has been incidental to cardiovascular fitness testing. The mean of maximum voluntary ventilation for 12 seconds was 181 L/min and during maximum exercise, the minute ventilation was 132.5 L/min [body temperature and pressure, saturated with water vapour (BTPS)]. The conclusions of Sharratt and Cipriano[21] were similar to those of Rasch and Brandt,[28] namely, that pulmonary volumes and functions of wrestlers were greater than those of nonathletes but were average compared with other well-trained athletes.

During maximum aerobic exercise, the average minute ventilation rate ranged from 129 L/min (in elite adolescent wrestlers)[25] to 156.6 L/min (in first-team members of the US Olympic team).[29] There were no significant differences in maximum minute ventilation rate between the first and second teams of the US Olympic team. Silva et al.[9] also found no difference between successful (155.7 L/min BTPS) and less successful (146.1 L/min) junior world wrestlers.

Sharratt[27] reported that in the elite senior level wrestler, maximum minute ventilation was low relative to the $\dot{V}O_{2peak}$ values and high lactate levels. This investigator suggested that elite senior wrestlers may hypoventilate during maximum exercise as a result of becoming conditioned to years of restricted breathing, and that successful wrestlers may be more tolerant of lactate physiologically or psychologically compared with the less successful wrestlers.

The $\dot{V}O_{2max}$, minute ventilation, and aerobic threshold (AT) of Korean national wrestlers [attained by a graded treadmill test from Yoon (unpublished observations)] was approximately 60 ml/kg/min, 141.6 L/min (BTPS), and 76.6% $\dot{V}O_{2max}$, respectively (table IV).

3.3 Flexibility

Flexibility refers to the range of motion in a given joint or sequence of joints. It is essential for everyday comfort and is important to the success of certain sports activities. In addition to promoting ease and grace of movement, flexibility may help to prevent injuries.

Surprisingly, research indicates that wrestlers are no more flexible than nonwrestlers.[30] Overall, wrestlers had less flexibility than other strength athletes such as weight lifters and gymnasts. However, considering the joint specificity of flexibility, it found wrestlers to have a greater rotation and abduction/adduction of the shoulder than nonathletic controls. While neck flexibility was also high in wrestlers, wrist flexibility was lower than that of nonathletes.[30]

Comparing the successful wrestler with the less successful wrestler, Stine et al.[10] and Song and Garvie[8] showed that flexibility may be a discriminating variable. For collegiate wrestlers, the sit and reach measurements were greater for the most successful group than for the moderately and least successful wrestlers.[10] No relationship appeared to exist between strength and flexibility, or between size of the wrestler and flexibility.[8]

4. Conclusion and Future Research

With such a minority of data on wrestling there are many paths for future research to take. Research on short-term effects could include verification of the rate of energy expenditure during intense wrestling and the role of acid-base balance in fatigue. Through the 1990s, the match duration for world-level competition was two 3-minute rounds in duration with a 30-second rest between rounds. Therefore, future research should be investigated to determine the interaction of aerobic (long-term energy-cardiovascular endurance) and anaerobic (immediate energy-strength and short-term energy-power/endurance) energy systems during wrestling and the recovery between matches.

Investigations of long-term effects include the influence of wrestling (isolated from other types of training) on: (i) the development of anaerobic path-

Table IV. Summary of maximum aerobic capacity and cardiorespiratory fitness of Korean national wrestlers[12]

	Duration (min)	$\dot{V}O_{2max}$ (ml/kg/min)	AT (% $\dot{V}O_{2max}$)	$\dot{V}O_{2max}$ (L/min)	LA_{max} (mmol/L)	$\dot{V}_{Emax}$ BTPS (L/min)	HR_{max} (bpm)	$\dot{V}O_2$/HR (ml/beat)	BF (breaths/min)	MET
Mean	14.43	60.24	76.55	4.39	8.34	141.56	197.5	24.01	64.57	17.25
± SD	1.57	5.13	2.92	0.70	1.71	21.99	8.8	5.47	6.43	1.45

AT = anaerobic threshold; **BF** = breathing frequency; **BTPS** = body temperature and pressure, saturated with water vapour; **HR** = heart rate; $\mathbf{HR_{max}}$ = maximal heart rate; $\mathbf{LA_{max}}$ = maximal lactic acid; **MET** = metabolic equivalent (1 MET = 3.5 ml/kg/min); **SD** = standard deviation; $\dot{V}_{Emax}$ = maximum expiratory ventilation; $\dot{V}O_2$ = oxygen uptake; $\dot{V}O_{2max}$ = maximal oxygen uptake.

ways for energy metabolism during performance; (ii) cardiovascular changes, such as left ventricle dimensions or $\dot{V}O_{2peak}$ during upper body work; and (iii) changes in the lean body mass, specifically muscle hypertrophy and bone mineralisation.

About 40% of matches at a Korean national competition (July 4 to 6, 2000) and at the freestyle world championships in Canada (June 27 to 29, 1997) were extended matches. This trend towards an extended wrestling match suggests that other types of training methodology should be taken into account. This might include examining the most effective use of wrestling, that is, continuous versus interval wrestling, to produce the fitness levels needed for success. Overtraining in the wrestler should also be studied because wrestlers have a long season of competition at scholastic and collegiate levels. A period for tapering and recovery may be lacking during the season because of having to make weight. Collectively, to become a successful wrestler it is suggested that development of appropriate and optimal training methods is key requirement.

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