A REVIEW OF PHYSIOLOGICAL ADAPTATION TO PHYSICAL TRAINING FOR ENDURANCE WITH SPECIAL REFERENCE TO RUGBY FOOTBALL

Part II: Training Methods

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This second part of the review follows survey of the scientific information available on training principles and human adaptive responses to exercise. It is divided into three sections:-

- (1) Training studies
- (2) A 'specific interval training' experiment
- (3) Training methods — conclusions.

1. Training Studies

Comparative studies of demonstrably fit and unfit subjects as typified by Johnson (1942) have shown lower oxygen consumption, heart rate and blood lactate in fit subjects during standardised easy work whilst in exhausting tasks the fit subjects attain higher maxima for oxygen consumption and external power output. Adaptation experiments where pre and post training measures are available for comparison are of greater interest since the process of adaptation can be related to a particular regimen of training activity. Knehr (1942) provides data which illustrates a commonly observed phenomenon. The initial adaptive responses to training are the most dramatic with increases in work ability being far in excess of physiological adaptation. It would appear that this latter phenomenon must be due to increases in skilled performance of, and habituation to, the task. A relationship probably exists here with the concept of specificity as discussed in Part I of the review, preceding the present part. Fardy (1969), reporting results obtained from tests on a group training for soccer using calisthenics, running and soccer drills and game situation practices, showed a very similar pattern of response to the training stimulus. Åstrand (1968) states that increased in the $\dot{V}O_2$ max with training are in the range of 10 – 20%, and points out that 'it is evident that natural endowment is the most important factor'.

Supporting evidence of percentage increase in $\dot{V}O_2$ max is provided by Ekblom et al (1968) reporting a group mean of 16.2% increase in $\dot{V}O_2$ max, Rowell (1964) 13.3% increase, Robinson and Harmon (1941) 16% increase, and Charlesworth (1971) 10% increase (for all his subjects involved in shuttle running but only 6% in his high fitness group). Kollias et al (1967) found virtually no change in $\dot{V}O_2$ max in cross country runners (already trained) when given further training on a

treadmill. The weight of evidence, therefore, strongly suggests that, whilst adaptation of aerobic processes does occur, such adaptation by no means accounts for the improvements in performance, since performance increases to the order of 50%, Ekblom (op. cit) are common. Though Nagle and Pelgrine (1971) working with teenage boys over a competitive track season found greater percentage changes in $\dot{V}O_2$ max than in performance even though initial values for $\dot{V}O_2$ max were high (ranging from 53.3 – 65.8 ml O_2 /kg/min), Caru et al (1970) on the contrary found young soccer players who were well trained were not significantly better in aerobic power than sedentary workers but were better able to use energy from anaerobic sources.

Use of anaerobically derived energy raises the problem of tolerance to the pain associated with high levels of blood lactate since this tolerance will vary. Clearly, psychological factors are important. Wilmore (1968) studying motivation and physical work concluded that increased performance brought about by motivation was not due to increases in the maximum levels of the respiratory variables but was made possible through increased anaerobic metabolism coupled with an increase in tolerance to the associated pain. Asmussen (1965) also supports the view that training and motivation play an important role in the levels of lactate which can be tolerated.

Attention had also been paid to the intensity, duration and frequency of training. Davies and Knibbs (1970) experimented with subjects working at 80%, 50% and 30% of $\dot{V}O_2$ max for 5, 10 or 20 minutes once, three or five times per week. Even at the highest intensity, duration and frequency, improvements were modest, ranging from 4 – 9 ml O_2 /kg/min. Sharkey and Hollman (1967) in a series of treadmill experiments concluded that work that did not elicit heart rates above 150 beats/min did not cause adaptation to occur. Support for the 150 beats/min training threshold is provided by Karvonen (1959) and Faria (1970). Durnin et al (1960) report some adaptation at 120 – 130 beats/min. Charlesworth (1971), (1972) compares results from interval shuttle running sessions in 11 minute periods with results given by Ekblom (op. cit) and Rowell (op. cit) and concludes that these very short intensive sprint running periods were as effective as 45 minute interval running and 90 minute middle distance running programmes/ in adapting physical work capacity. The shuttle running it should be noted is specific to the

games situation. He made a further comparison with a six item circuit training schedule, finding that there were no significant differences between groups on the basis of change in VO_2 max expressed in l/min (though when expressed in ml O_2 /kg body weight/min, shuttle runners were significantly better). Shuttle runners had significantly greater work ability and this was taken as evidence of improved anaerobic capacity and tolerance. (Efficiency changes were not considered).

In view of the foregoing evidence, heart rate data obtained from match play in two major games on one subject (J.E.K.) is of interest. Telemetric techniques were used and results were as follows:-

	Highest Heart Rate beats/min	$\bar{x}$ Heart Rate beats/min
Playing Soccer	185	166
Playing Rugby	182	163

N.B. Subject is a rugby player.

Highest heart rates correspond to maximum values obtained in exhausting treadmill runs and in training. Clearly this subject was loaded physiologically enough to elicit adaptation.

The assessment of physiological load during performance of the game is a valuable source of information which can be applied to the design of training experiments. The following section on a soccer specific interval training experiment we have carried out recently, was designed on the basis of data obtained from analysis of match play and simultaneous monitoring of heart rates from a group of professional footballers.

2. A 'Soccer Specific Interval Training Experiment'

The effects of specific interval training (Group A), typical middle distance schedule (Group B) and a general programme of physical activity (Group C) were compared using volunteer students assigned randomly to the groups. Overload was applied systematically to the

GROUP B Standard pattern 200 m interval running with 60 seconds rest between runs in each set

Fig. 1. Diagrammatic representation of schedules used in the training experiment during the first week of the 8 week programme of training.

first two groups and for these groups training was supervised. Fig. 1 shows the schedules from Group A and B for the first week. Overload was applied by building in gradually another set of 'reps.' for Group A within the 25 minute period and by reduction of intervals for Group B as well as introduction of more sprints.

Pre and post training all subjects were given two types of treadmill test to exhaustion. Test 1 was a standard form of test. Test 2 involved alternating sprinting and jogging on the treadmill. (This was an attempt to use a more specific form of test but results were disappointing: details will be given in subsequent publications). Respiratory measures were obtained as shown in Table III. A 600m run test was also applied to all subjects. Tables I, II and III provide descriptive statistics for the key parameters measured. Reliability coefficients (r_{11}) were as follows, Test 1 treadmill run time $r = 0.87$, $\dot{V}O_2$, $r = 0.84$ and 600m time $r = 0.86$. Analysis of co-variance was used to test for significance of differences between these groups in this randomized group design experiment, Edwards (1959). All differences were found to be non-significant.

Tables IV and V show correlations between the two performances measured and $\dot{V}O_2$ max/kg. The tendency is for pre-training correlations to be better than post-training correlations whilst there is little change for the Control Group (C). These results indicate that group training leads to greater homogeneity and that $\dot{V}O_2$ /kg loses its predictive value with the interplay of other factors. (The multiplicity of factors determining capacity for endurance task performance has been reviewed previously).

Heart rate data obtained during sessions in the 5th week of training indicated that both treated groups were working at rates eliciting between 20 – 40 beats greater than the 150 beats/min training threshold with a somewhat greater load on Group A.

The fact that Group A is not significantly better than the other groups in performance or on the basis of physiological parameters is of interest. Perhaps the techniques employed are too crude or the factors measured are not the key ones, hence the failure to establish a specific training effect. Certainly, evidence is once more provided to support the view that aerobic capacity is by no means the only physiological adaptive response to training.

3. Training Methods – Conclusions

Determination of the most effective training intensity, duration and frequency and also the effectiveness of specific training items in the selection or development of training programmes is of fundamental importance. Our

own difficulties in provision of sufficient overload to partially trained subjects to demonstrate a significant training effect is salutary.

Whilst maintaining our view that specificity must be a primary aim in the design of training programmes much can be learned from methods used in training middle distance runners, Doherty (1964), since such athletes have many attributes which are desirable in the player of major field games. Christensen et al (1960) whose work is summarized by Åstrand and Rodahl (1970) gives added weight to the value of intermittent exercise. Schedules which produce near maximal physiological response tax both aerobic and anaerobic capacity and there is the possibility of adaptation in both of these fundamental metabolic processes. To these ends heart rate measures can be used as an index of involvement and to ascertain that overload situations are being created. One suspects that overload may not occur or not occur frequently enough to produce adaptation in training for many amateur games players. The adaptation that does occur in such cases may be more by skill improvement and habituation in response to regular match play. Match play may, in fact, provide the only true overload leading to physiological adaptation.

Assessment of physiological load and hence of overload can be achieved using techniques developed by Brooke and Knowles (1974). The construction of a heart rate/oxygen uptake curve from laboratory data can then be used to determine the percentage of physical work capacity required in a training or match play situation by interpolating on this curve the heart rate data obtained in these field situations. Brooke and Knowles (1972) report a transitory electrode device (T.E.D.) which allows for the rapid large scale monitoring of heart rates in field conditions. Research studies of this type undertaken on rugby players could be used to assess various training activities. The club coach could then administer training routines based on this research using a stop watch as his means for controlling intensity of training and then be more certain of providing adequate overload. It must be stressed that overload should be applied in a progressive manner. In our own training studies the fact emerges that, for moderately trained people, intermittent running, resulting in heart rates in excess of 180 beats/min, is required to produce even modest adaptation. This type of running really hurts. Since there was no significant difference between the two forms of training (specific and non-specific) the conclusion may be drawn that both methods are equally effective thus providing the coach with alternative forms of training which can be used to provide variety and relieve monotony.

Although intermittent running has been stressed, the value of continuous running at or near $\dot{V}O_2$ max has a place in a balanced programme since, in addition to its

effects on the aerobic system, efficiency of running may well be improved. Efficiency in the playing of rugby with its many and varied individual and unit skills must also depend upon the neuro-muscular and psychological factors influencing the performance of these skills. The subtle interplay of these factors with the physiological factors probably leads to the final statement of the nature of such efficiency. It has been previously acknowledged that specificity is an important training principle and coaching in individual and unit skills in part caters for this.

Our own attempts to incorporate the specific running element into interval training provide inconclusive results. It is necessary to continue the search for the role of specific training (as opposed to coaching) activities. Coaches have introduced their own 'Rugby Circuits' and the RFU Coaching Bulletin (1970) provides an example. Assessment of such specific training practices remains largely subjective: the danger is pointed to by Brooke, Knowles et al (1970) who failed to obtain correlations between leg strength measures and length of soccer kick. Another problem associated with specific training is that without close supervision the breakdown of skill rapidly becomes apparent. For example, the execution of repetition dives (an item often chosen by rugby circuits) may satisfy the criteria of specificity and overload when executed by a scrum half, but usually degenerates into "flop and plop" when executed by a prop forward.

Pressure training, which is a common technique employed in Soccer and Basketball merits closer examination and development of ball carrying, retrieving and passing practices could lead to their intensification into true pressure training, providing for both specificity and overload. Zalenka et al (1967) linking metabolic function and skill assessment in one test and Detchon (1970) providing examples of specific soccer training could be useful indicators of methods which could be adapted to rugby use.

A factor in the preparation of rugby players which should not be neglected is that time available at all levels is limited owing to the amateur nature of the game. Furthermore, facilities for training are often inadequate although sports halls, floodlit areas and all weather training surfaces are increasingly available. For a majority small standard gymnasias available for a once or twice weekly training session is still norm. The conclusion of Charlesworth (op. cit) on the effectiveness of shuttle running in comparison with circuit training is noteworthy. Shuttle running in various guises (e.g. relays) and for inclusion in circuits is recommended as a means of combating restricted space and overcrowding. It is in these situations that the problem of providing sufficient overload for all players attending a session is highlighted, for the range of age, position, aspiration and initial level of adaptation is usually great within one

club. Attempts should be made to categorize and group players in order that they all be subjected to appropriate forms of specific progressive overload. This view is supported by Shephard (1967) who criticises Darling's (1947) statement of fitness and himself opines that "fitness should be assessed from the performance of a fully learnt task".

The final and most important conclusion that can be drawn from this review is that there is room for a great deal more study and research into the training of rugby footballers. Perhaps more people with the relevant professional skills will apply these to the development of a more scientific approach to the preparation of players. Three approaches are suggested:-

1. analysis of the physical performance requirements during match play.
2. laboratory and field experiments designed to study adaptation of the factors identified in match play.
3. the application of research findings to practical development of training techniques.

Perhaps the RFU will financially support such studies in the future. The outcome could benefit the game at all levels. The long term value to the game of an assessment of its physical benefit to the ordinary club player may be greatest since the results may be such that they commend the game to educators in this age of increased physical education options and curriculum development in our schools.

Consider Poulton's (1970) statement:-

"Man's adaptability to environmental conditions and his physical fitness have profound impact on his pursuits and the calibre of their performance".

There is a message here for all concerned with the game. We are perhaps most aware of the calibre of performance at international level whilst at the humbler club level premature retirement may be due to the unpleasant experience of a player employing a level of fitness far below that demanded by the pursuit of a rugby ball. Clearly the game has a responsibility at all the levels at which it is played and by increasing our knowledge of physical adaptation to training for this endurance activity that duty will be better discharged.

Table I:

Descriptive Statistics of the Performance Times (Sec.) of Treadmill Test 1

	Group A			Group B			Control Group		
	x	S.D.	n	x	S.D.	n	x	S.D.	n
Pre-training	344.2	54.16	10	322.6	47.42	11	306.1	47.09	13
Post-training	384.5	40.84	11	377.2	39.14	11	342.7	56.31	11
Difference	40.3 (11.8%)			54.6 (16.9%)			36.6 (12.0%)		

Table II:

Descriptive Statistics of the Performance Times (Sec.) of the 600m Run Test

	Group A			Group B			Control Group		
	x	S.D.	n	x	S.D.	n	x	S.D.	n
Pre training	108.2	6.01	10	108.1	5.44	11	113.1	8.80	13
Post-training	103.3	6.94	11	104.0	7.74	11	107.2	6.17	9
Difference	4.9 (4.5%)			4.1 (3.8%)			5.9 (5.5%)		

Table III:

*Descriptive Statistics of Max. $\dot{V}O_2$ /kg (in ml. per min.) Taken From Measurements During the Treadmill Test Performances***A Treadmill Test 1**

	Group A			Group B			Control Group		
	x	S.D.	n	x	S.D.	n	x	S.D.	n
Pre-training	55.2	7.47	10	52.7	7.24	11	53.4	6.65	13
Post-training	57.1	8.69	11	55.3	8.43	11	56.1	9.12	11
Difference	1.9 ml (3.4%)			2.6 ml (4.9%)			2.7 ml (5.1%)		

Table IV:

Correlation of Max $\dot{V}O_2$ /kg from two treadmill tests with 600m run times

		Treadmill Test 1 Max $\dot{V}O_2$ vs 600m run time		Treadmill Test 2 Max $\dot{V}O_2$ vs 600m run time	
Group A	Pre-training	0.046	n = 10	-0.445	n = 7
	Post-training	0.326	n = 11	0.035	n = 11
Group B	Pre-training	-0.592	n = 11	-0.513	n = 11
	Post-training	-0.208	n = 11	-0.096	n = 11
Control Group	Pre-training	-0.219	n = 13	-0.278	n = 13
	Retest	-0.164	n = 11	-0.383	n = 11
	Post-training	-0.031	n = 11	-0.017	n = 9

Table V:

Correlation of Max. $\dot{V}O_2$ /kg from Treadmill Tests 1 and 2 with Treadmill Tests Performance Times

		Treadmill Test 1		Treadmill Test 2	
		r	n	r	n
Group A	Pre-training	0.518	10	0.555	7
	Post-training	0.491	11	0.190	11
Group B	Pre-training	0.707**	11	0.502	11
	Post-training	0.257	11	0.096	11
Control Group	Pre-training	0.708*	13	0.565**	13
	Post-training	0.774	11	0.546	9

** significant at the 5% level of confidence

* significant at the 1% level of confidence

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