

Design of Training using Scientific Data – A Practical Approach as a National Coach

Bo Omosegaard

Danish Badminton Association

In my speech I will touch on these topics:

- My general considerations regarding scientific data and elite training using badminton as an example
- How to use scientific data for badminton training using the development in Danish badminton 1988 – 1996 as an example
- The key points of training planning and testing for the 1996 Olympic Men Singles Badminton Champion Poul-Erik Hoyer Larsen

Danish badminton in the late 1980-ies

Up until 1980 the very high level of Danish badminton was based entirely on a strong club system with 8 national leagues and a high number of regional and local leagues. All training was centred in and around the clubs. During the decade a national squad developed, and at the beginning of the 1990-ies a full time training set up was in place.

Therefore, following the traditional way of training, in the late 1980-ies match practice was by far the most important training element – maybe 80% of the training time – and most of the players did running (distance or long interval running) once or twice a week!

Despite that fact Danish badminton was ranked 2-3 in the world in the beginning of the 1980-ies but with a strong downward trend during the decade. There were two main reasons for that: Peoples Republic of China entered the badminton scene and badminton was nominated an Olympic sport starting 1992 in Barcelona. Consequently on a world wide scale the resources allocated to badminton grew immensely starting in the latter part of the decade.

The Danish Project “Olympic Games 92” – “OG 92”

This project OG 92 was launched in 1988 by the Danish Badminton Association. The initiative was created by the current National Coach Steen D. Sorensen. Project manager was Assistant National Coach Henrik Fahrenholz. Our view on the general Danish player profile was: Mentally strong, technically good, tactically excellent and physically poor – with lack of speed on court being the biggest problem.

Therefore the main purpose of Project OG 92 was to develop a concept of physical training and build a new training culture including physical training among the National squad.

I was appointed responsible for development and implementation of

- Training Planning
- Testing
- Strength training programmes
- Plyometric training programmes

among the National Elite Squad. I wanted to use a scientific approach, but in doing so, I faced some difficulties.

The scientific basis for Training and Training Planning on elite level

Training planning

Like many other complex sports badminton suffers from a substantial lack of scientific data. Regarding training planning specifically on badminton no controlled long term studies meeting scientific standards were available (and

at present not available either!).

Therefore I based the training planning for badminton on:

- Research done on qualities important for badminton e.g. strength and power training, motor learning, oxygen uptake.
- Research done on “measurable sports” like athletics, swimming and weight lifting.
- Personal experience on training planning working with international badminton players.

Physical training

On the other hand much more scientific data are available covering the physical and technical profile of badminton.

In summary training and training planning for badminton at the project OG 92 were therefore based on:

- The scientific knowledge available on badminton
- Experience as a coach
- Knowledge and experience from other sports
- Intuition and improvisation
- Trial and error, think outside the box!

The profile of badminton and the individual player profiles were the basic tools for creating the individual training programmes.

Physiological profile of badminton

During the 1980-ies a well documented physical and biomechanical profile of badminton was established – see references for further details. A very short summary:

Physical demands – energy systems

The average maximal oxygen uptake for Danish elite male players 1988 – 1995 is 64 ml/o₂/kg and females 55 ml/o₂/kg.

The relative loads during games are

	<u>1979</u>	<u>2003</u>
Men’s singles	92%	92%
Ladies singles	88%	90%
Men’s doubles	81%	89%
Ladies doubles	71%	86%
Mixed men/ladies	77/66%	87/82%

Work–rest ratio typically between 40-60 and 50-50, but the length of rallies and breaks can vary from 1-90 sec. Average rally and break length are 6-10 sec – the length of the breaks are much more uniform than the length of the rallies.

The duration per match can vary between 15–120 min but usually 20 – 60 min. “A typical 15-10 set” lasts approximately 20 min.

During tournaments on National level a player is facing up to 10 matches per day if playing all 3 events. On international level 1 – 2 matches per day per event.

The conclusion is that the CrP, ATP and lactic acid systems deliver up to 90% of the energy to the muscles, but it is the oxygen system which is the 100% prerequisite for keeping the energy systems going.

The training conclusions on the energy systems

Training of maximal oxygen uptake and endurance at >85% Vo₂ max during short interval exercise is of paramount importance - using mainly interval training methods and varying work periods and/or intensity causing regular lactate accumulation and removal.

Physical demands – muscular demands, foot work

Biomechanical analysis was used to establish the muscular demands related to the foot work. Fig. 1 shows an example of data collected covering the movement from the playing centre to the long backhand corner and back to playing centre.

The main conclusions are, that badminton foot work can be divided into 4 phases. Each phase has its own characteristics:

- 1 - Foot work in the playing centre using a split jump / pre-tension jump. Typically 85-100% of maximal functional strength is developed in every push-off.
- 2 - Movement to hitting area using many different movement patterns. Sub-max to max speed.
- 3 - Foot work in connection with the stroke: Lunge, Scissor jump, two feet landing, on and two legged jumps. Using typically 85-100% of maximal functional strength in every push-off.
- 4 - Movement back towards the playing centre using many different movement patterns. Sub-max to max speed.

The typical push-off times in the corners and “low speed push-offs” in playing centre are:

- 1 legged push-offs 0.52 sec. Common variation 0.38-0.95
- 2 legged push-offs 0.32 sec. Common variation 0.16-0.55

The stretch-shortening cycle with preloading movements initiating all push-offs is an integrated part of badminton foot work technique. Fig. 2 shows an example from the push off in the playing centre.

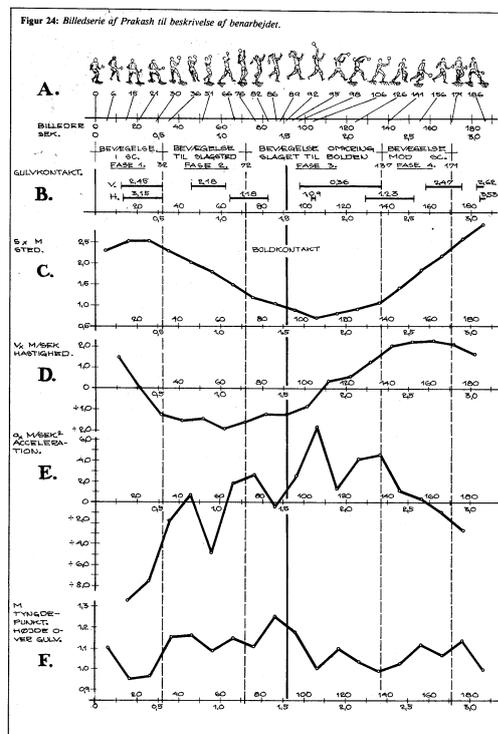


Fig. 1. A biomechanical analysis

Frame / Seconds

Floor contact: V=left foot. H=right foot

Position (players centre of gravity) relative to the base line

Velocity – direction towards the net positive values

Acceleration – direction towards the net positive values

Centre of gravity – height over the floor

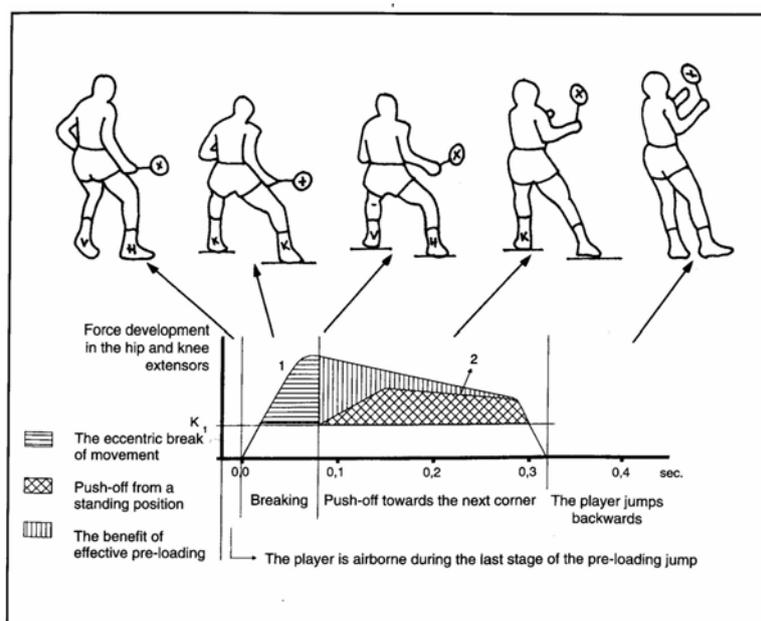


Fig. 29. A player moving from the backline towards the playing centre during the last stage of the pre-loading jump (1st. picture). The player lands on both feet (2nd. picture) and, as the next shuttle comes to the backline the person 'brakes' (3rd. picture) and pushes off on both feet (4th. picture) and jumps backwards (5th. picture). K_1 is the force which the muscles have to develop in order to carry the body.

Curve 1 illustrates the development of strength in the knee and hip extensors during a typical push-off from the playing centre corresponding with the series of pictures.

Curve 2 illustrates the development of strength at push-off from a standing position in the playing centre.

The horizontally hatched area corresponds to the break of movement towards the centre of play. As the push-off towards the backline starts, a very high tension in the push-off musculature is already present. The tension falls during the push-off as the speed of contraction in the muscles is increased.

The cross-scattered area corresponds to a push-off from a standing position. At the onset only a small tension is present in the push-off musculature, namely the tension needed to carry the bodyweight. During the first third of the push-off the tension has to increase and this results in a slower push-off than the one in curve 1.

The vertically hatched area corresponds to the benefit of effective pre-loading. (*20)

Fig. 2. The pretension jump and push off in playing centre

The number of push-offs during a match is huge: A typical "15-10 set" lasting 20 minutes, contains approximately 300 returns per player/pair = 600 push-offs. For a singles player that amounts to 1800 maximal or near maximal push-offs in a 1 hour match!

Training conclusions on the muscular demands, foot work

Quality

Maximum concentric strength
Maximum eccentric strength
RFD (Rate of Force Development)
Near maximum push-off endurance
Coordination

Training method

Heavy Resistance Training > 80% of 1 RM
Heavy Resistance Training - Eccentric Training
Plyometric training
Mainly on-court training
Technical training

Physical demands – muscular demands, stroke production

Very high racket speeds are common in badminton.

	Shuttle	Racket
Underarm lifts	64 mph / 103 km/h	44 mph / 70 km/h
Fore- and backhand clears	110 mph / 177 km/h	75 mph / 120 km/h
Forehand smash low speed	145 mph / 230 km/h	99 mph / 159 km/h
Do very high speed	209 mph / 335 km/h	143 mph / 229 km/h

Even what appears to be a "gentle" movement involves very fast joint actions. E.g. the forward swing in an overhand clear is over in less than 0.1 sec. and technical details are virtually invisible to the naked eye.

Therefore a biomechanical analysis was used to identify the technical elements and to establish the muscular demands related to stroke production. Fig. 3 shows an analysis of an overhand forehand smash.

In this typical low speed smash the head of the racket is accelerated from 67 to 166 km/h in 0.05 sec. In this example the angular velocities of the most important movements are forearm pronation 3000 dg/sec and shoulder inward rotation 1300 dg/sec.

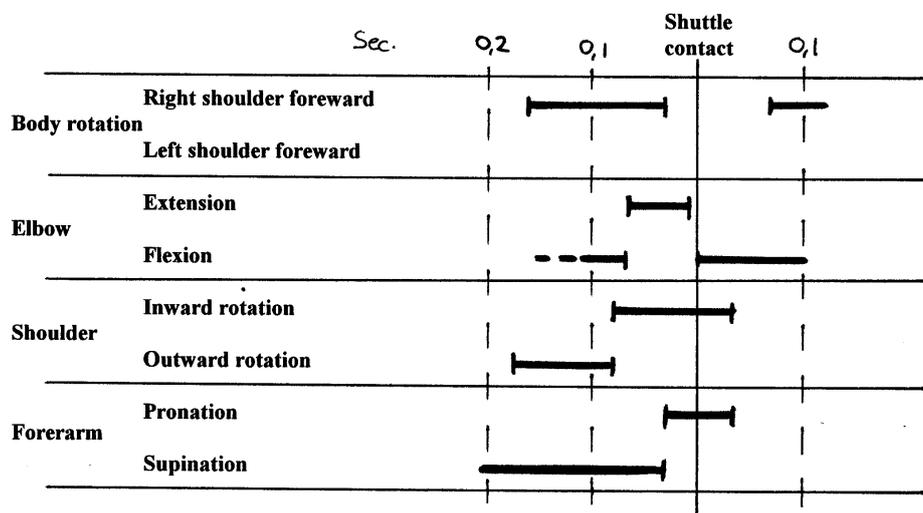
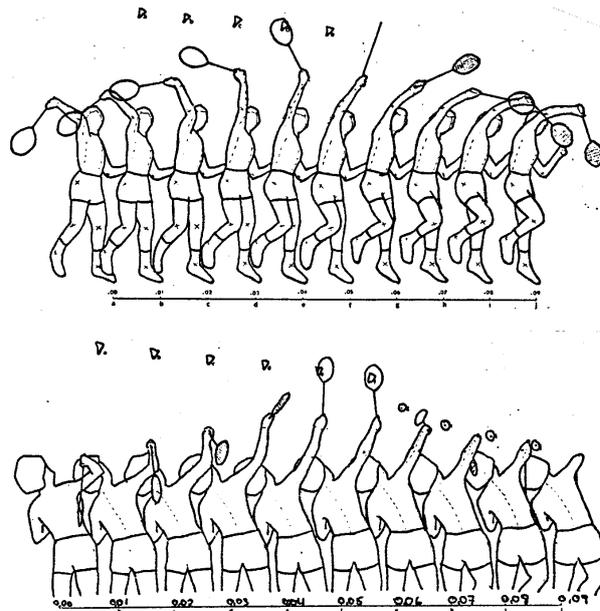


Fig. 3. The overhand forehand smash

Training conclusions on the muscular demands, stroke production

Traditionally the training regimes associated with such fast movements were based on “speed-strength”; e.g. strength training using a combination of low resistance (10-40% of 1RM) and maximum speed of movement. Unfortunately my personal experience using this training regime has shown no improvements at all. A closer examination of the biomechanical analysis provided a possible explanation.

Breaking down the hitting action (fig. 4.) in the forehand smash reveals the “whip-like action” moving from body centre to distal parts – a pattern well known from other sports too. But it also shows that each movement involves a stretch-shortening cycle with maximum eccentric and concentric contractions.

Therefore I focused on these qualities in training for racket speed and power:

Quality	Training method
Rate of Force Development	Plyometric training
Maximum concentric strength	Heavy Resistance Training > 80% 1 RM
Maximum eccentric strength	Heavy Resistance Training - Eccentric Training
Coordination	Technical training
“Near maximum endurance”	Functional endurance training e.g. smash endurance

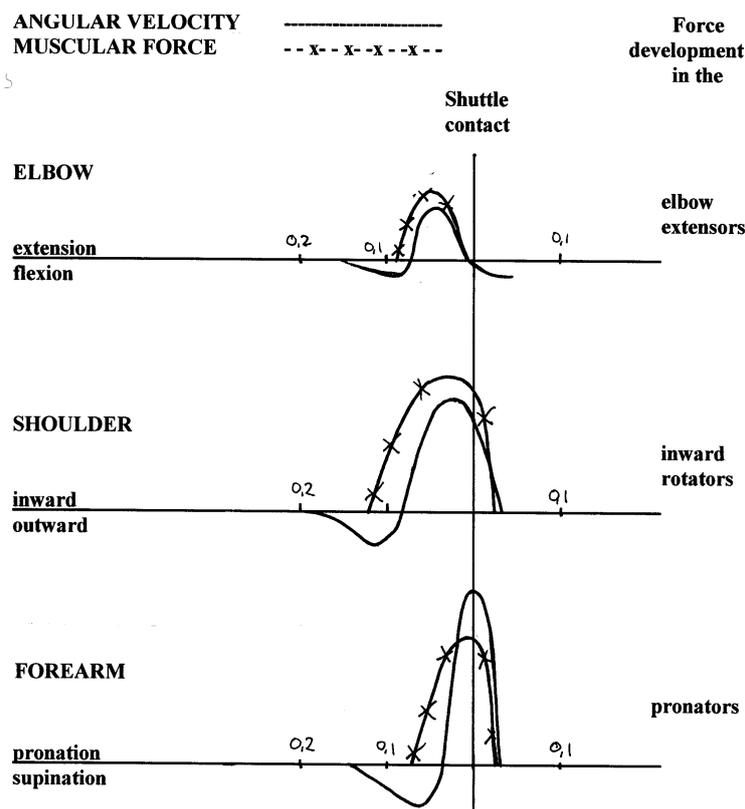


Fig. 4.

Player profiles and testing

The players went through a wide range of tests. The purpose was to

- Establish individual profiles as a starting point
- Monitor the progress of the individual player
- Monitor the efficiency of the training methods
- Collect data as an ongoing research developing new training concepts

The actual tests

This is the full range of tests:

Anthropometric data	Body weight	Measured at the Team Denmark Test Centre (TD TC)	
	% body fat	TD TC	
Energy systems	Vo ₂ max on tread mill	TD TC	
	Lactate test on tread mill	TD TC	Running uphill with 7° incline in (15 sec work + 15 sec rest) periods. Men: 18 km/h, woman 16 km/h
	“Side to side”	On Court Test (CT)	25 times from side to side on a badminton court at max speed – “all out”. Work time ranging from 38-55 seconds.
Explosiveness	Jump and reach - 2 legs	In Training Hall (TH)	
	Jump and reach - racket side leg	TH	
	Jump and reach – non racket side leg	TH	
	Lounge jump test	TH	See fig. for information
Strength	Pull down	Daily Strength Training Facilities (SC)	
	Abdominal crunch	SC	
	Back extension	SC	
	Bench press	SC	
	Leg press - racket side leg	SC	
	Leg press - non racket side leg	SC	
	Leg press - 2 legs	SC	

	Flyes	SC	
	Reversed flyes	SC	
Smash speed	Forehand smash	CT	High Speed Camera method with mathematical extrapolation of shuttle speed back to racket-shuttle impact
	Backhand smash	CT	
Knee extension – racket side leg	5 d/s conc.	TD TC	Kin Com isokinetic test apparatus
	90 d/s conc.	TD TC	
	180 d/s conc.	TD TC	
	240 d/s conc.	TD TC	
	90 d/s ecc.	TD TC	
Knee extension – non racket side leg	5 d/s conc.	TD TC	
	90 d/s conc.	TD TC	
	180 d/s conc.	TD TC	
	240 d/s conc.	TD TC	
	90 d/s ecc.	TD TC	
Knee flexion – racket side leg	5 d/s conc.	TD TC	
	90 d/s conc.	TD TC	
	180 d/s conc.	TD TC	
	240 d/s conc.	TD TC	
	90 d/s ecc.	TD TC	
Knee flexion – non racket side leg	5 d/s conc.	TD TC	
	90 d/s conc.	TD TC	
	180 d/s conc.	TD TC	
	240 d/s conc.	TD TC	
	90 d/s ecc.	TD TC	
Forearm pronation – racket arm	5 d/s conc.	TD TC	
	90 d/s conc.	TD TC	
	180 d/s conc.	TD TC	
	240 d/s conc.	TD TC	
	90 d/s ecc.	TD TC	

On average one time per year the full range of tests was carried out. The tests not involving The Team Denmark Test Centre were carried out twice a year. On top of that 1RM max tests were carried out on the strength training equipment every 2 to 3 month as part of the strength training programme.

Examples of how to use these tests as a guiding tool

Strength - explosiveness

The Jump and reach – 2 legs, Jump and reach – 1 leg and the Lounge jump test are reflecting the players explosiveness and strength, but in different combinations: Jump and reach – 2 legs being mostly depending on explosiveness and the Lounge jump test being mostly a badminton specific strength test.

Fig. 49. The lunge-jump test. Note that the player is left-handed.



A The length of "a standing lunge" is marked by a piece of tape at the heel. Note the stretched out wrist, the vertical lower leg and the vertical thigh



C The left fore-finger immediately marks an even better attempt if this has been achieved.



B The test leader marks with his right fore-finger the best attempt so far.



D If the player recovers his balance behind the starting line, the right fore-finger "takes over" the marking to confirm the best result. If not, the left fore-finger is lifted and the attempt does not count.

Fig. 5. The lounge jump test

Both qualities are of paramount importance for a badminton player and the combination is reflecting the players chances for reacting and moving fast in different situations. This is illustrated in fig 6.

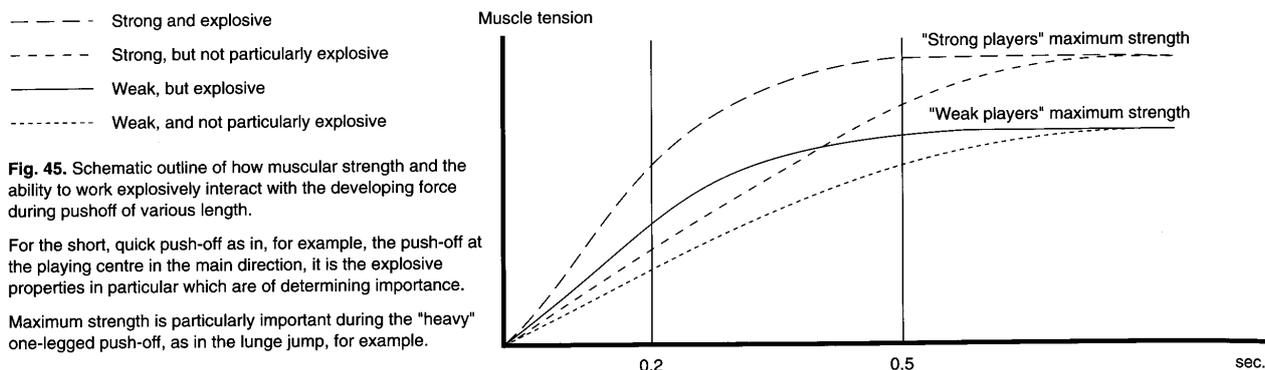
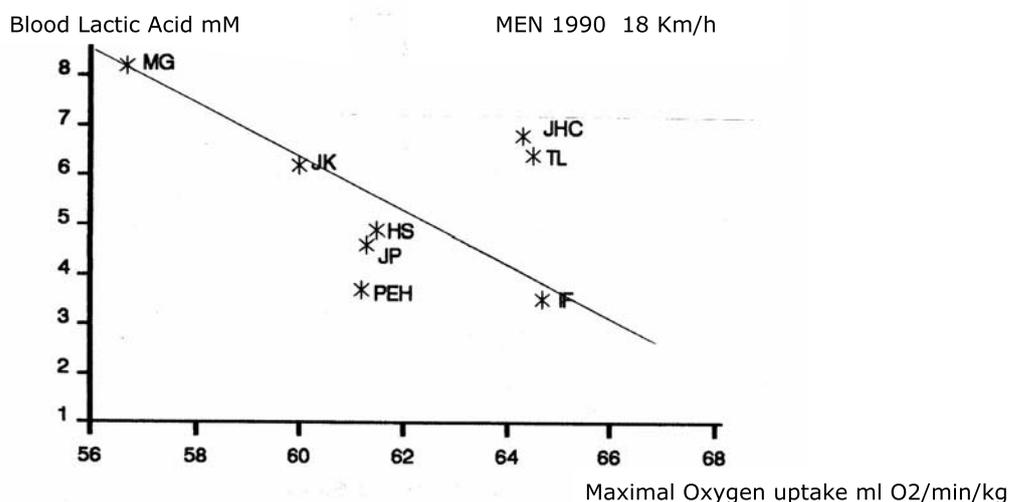


Fig. 6 Explosive vs. strong player

By comparing the 3 different tests each player can be characterized according to fig. 6. This proved to be a very, very useful tool in controlling the balance between training of maximum strength, explosive strength and plyometric exercises.

Aerobic high intensity – aerobic very high intensity – anaerobic training

Also we combined the traditional V_{O_2} max tread mill test with the more badminton related test running uphill with 7° incline in (15 sec work+15 sec rest) periods (men at 18 km/h, woman at 16 km/h). We wanted to use these tests as a tool to decide the balance between 1) aerobic training with high intensity (70-90% of V_{O_2} max) using e.g. long interval training 2) aerobic training with very high intensity (90-100%) using e.g. short-short interval training and 3) anaerobic training. A typical relation between the two tests is illustrated in fig 7



Both tests were very good for monitoring the aerobic fitness of elite badminton players – but as a guiding tool as explained above it did not work out for us.

Muscular strength and smash speed

Searching for factors related to smash speed we found a significant relation between forehand smash speed and eccentric strength of the forearm pronation at 90 d/s and also, but not as strong, between forehand smash speed and concentric strength of the forearm pronation at 5 d/s. This was true for both men and woman and is illustrated in fig 8.

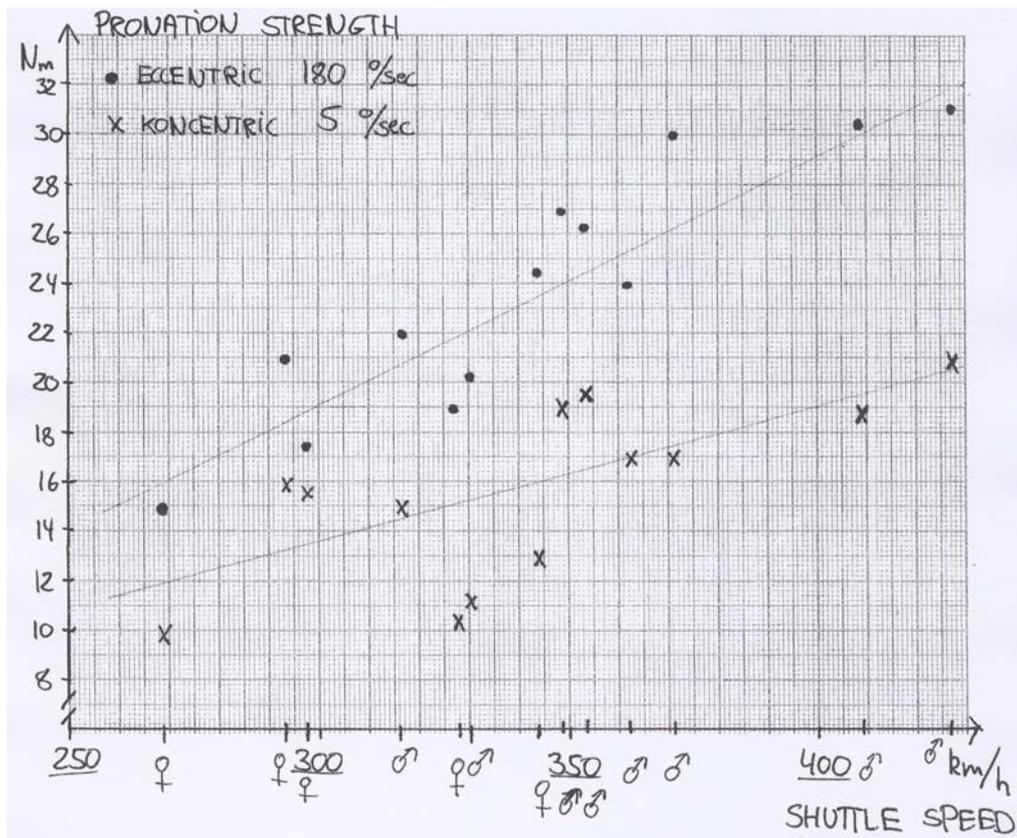


Fig. 8. Smash speed vs. forearm strength

Strength training for the forearm pronators became part of the strength training programme. However, improved maximum strength in the forearm pronators in itself had no impact on smash speed. But in combination with plyometric and/or technical training the smash speed increased.

These data represent a non scientific registration on small groups of elite players:

Improvement in strength of the shoulder and forearm rotators:	27%	31%	34%
Change in shuttle speed following no smash specific training:	-4 - +1%		
Change following functional plyometric training (among them squash racket):	+4 - +11%		
Change following technical and functional plyometric training:	+10 - +22%		

Poul-Erik Hoyer Larsen – milestones on his way to winning the Olympic men singles title in 1996

Poul-Erik Hoyer Larsen was 23 years of age when he joined the project OG 92 in 1988. He was throughout his career a technically brilliant player with a very deceptive style, capable of playing direct winners from almost all positions on court. Unfortunately this style is vulnerable on the “below average days” resulting in a high rate of unforced errors. This was especially a problem when he was under physical pressure playing long, hard matches with the opponent dictating the pace. Physically his aerobic capacity was good but speed on court was a problem.

A typical week plan 1984-1988

Total training Hours per week	20 hours/week + competitions
Match practice	17 – 19 hours/week
Routines with technical, tactical or physical objectives	-
Aerobic training	Running 1-2 times/week. Distance or long interval training.
Strength training	1-2 times/week. Muscular endurance e.g. circuit training
Plyometric training	-

Joining the project OG 92 his overall training plan changed totally.

A typical week plan 1988-1993

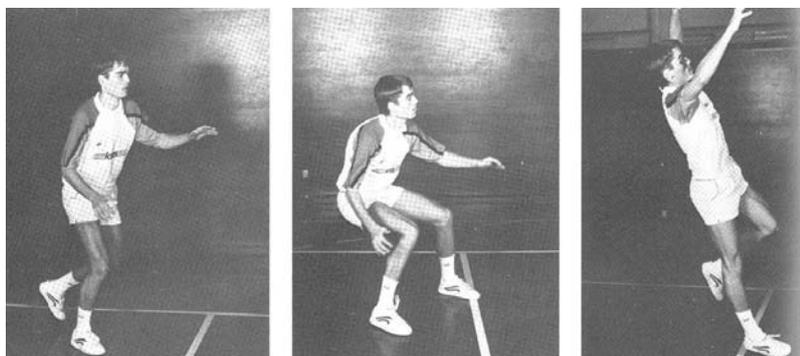
Total training Hours per week	24 hours/week + plus low priority competitions
Match practice	7 hours/week
Routines with technical, tactical or physical objectives	7 hours/week
Aerobic training	Running or other activities 2-3 times/week. Short or short-short interval training.
Strength training	3 times/week – 5 hours. Concentric max., eccentric max. , power
Plyometric training	2 times/week

Following the new training he gradually increased the training volume, the average training intensity and introduced new training regimes. The selected test results below reflect those changes.

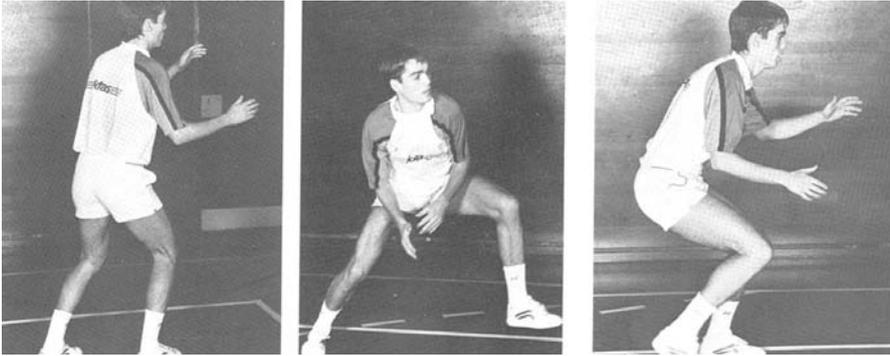
Poul-Erik Hoyer Larsen	Dec. 88	May 89	Sep. 89	Jan 90	May 90	Oct. 91
Body weight – kg	75.5	76.5	75.9	76.2	76.8	76.2
% body fat - % of BV	9.0	9.0	8.0	9.0	9.5	9.5
$\dot{V}O_2$ max on tread mill – lO_2 /min/kg	66.2		64.7	61.2	57.3	61.2
Lactate test on tread mill – mM La at 7°/15+15/18 km/h	2.6		2.8	3.7	4.3	3.5
“Side to side” – sec		42.7	43.34	44.65		42.33
Jump and reach - 2 legs – cm	54.0	61.5	64.5	61.5	61.5	64.5
Jump and reach - racket side leg – cm	42.5	49.0	50.5	50.5	51.5	53.5
Jump and reach – non racket side leg – cm	42.5	47.0	48.5	49.5	49.5	49.5
Lounge jump test – cm	20.5	29.5	32.0	41.5	43.0	61.0
Pull down - kg	100		135			160
Leg press - racket side leg – kg	105	130	150	150	150	160
Leg press - non racket side leg – kg	90	115	120	120	125	130
Leg press - 2 legs – kg	180	220	250	250	250	275
Forehand smash – km/h	315	369		340	365	
Backhand smash – km/h	254	275		279	260	

Poul-Erik Hoyer Larsen: Selected test results from OG 92

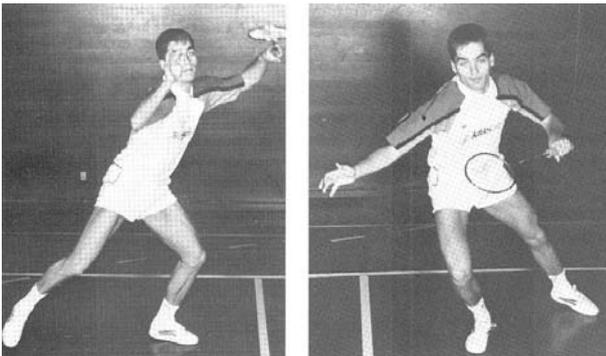
One of the biggest challenges for player and coach is to benefit on court from the improved physical qualities following physical training. In badminton that is especially true for qualities related to technical aspects like smash speed and speed on court. Fig 9 illustrates some examples of the badminton specific plyometric exercises being part of Poul-Erik Hoyer Larsens training.



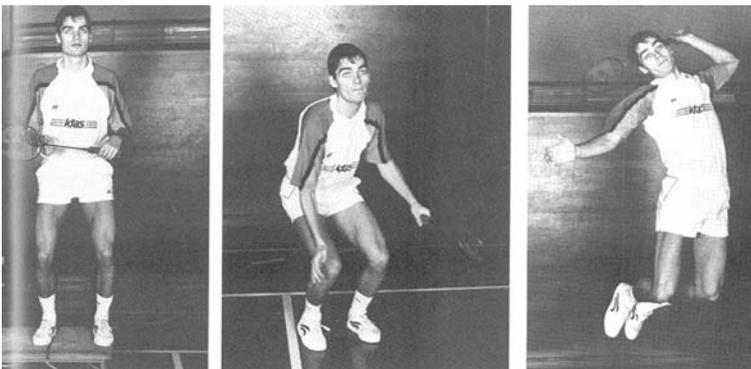
Push off in playing centre



Scissor jump at the base line



Two feet landing in the long forehand corner



Jump smash after a pretension jump for a plinth

Fig. 9. Poul-Erik Hoyer Larsen. Examples of badminton specific plyometric exercises.

Olympic Games Barcelona 1992

Poul-Erik Hoyer Larsen participated in the 1992 Olympics in Barcelona. Only a narrow defeat in the quarter final loosing 15/10 15/12 to the Indonesian player Ardy kept him from winning a medal.

The main conclusion following the evaluation of the Olympic Games: Poul-Erik was physically on the level needed to win the title, but improvements could still be achieved on the mental side.

The period 1993-1996

As a consequence Poul-Erik started working with a sports psychologist, and continued to do so for the next 3 years.

A major problem appeared in 1993. Shorts periods of knee pain that had occurred since 1987 became a consistent problem. Diagnosed with a serious damage to the cartilage on the left knee cap (Poul-Erik is a left hander) he had to change his over all training plan to reduce the load on the left knee and to include a lot of rehab and preventative training.

A typical week plan 1993-1996:

Total training Hours per week	24 hours/week + plus low priority competitions
Match practice	5 hours/week
Routines with technical, tactical or physical objectives	6 hours/week
Aerobic training	Bike training 2-3 times/week and running or other activities 1 time/week. Long interval, short or short-short interval training.
Strength training	2 times/week – 4 hours. Concentric max., eccentric max. , power
Rehab and preventative training	4 hours/week: Balance, coordination, specific strength, foot work technique
Plyometric training	1 time/week

The rehab training proved successful. A MR scanning late 1994 showed substantial improvements in the cartilage. Benefiting from the 5 year period of building up his physique, he was now able to maintain that high level by a slightly reduced amount of physical training. Mentally he improved now being able to deal with both psychological and physical tough situations on and off court.

In 1995 he won his first major title, becoming the All England men singles champion, playing to the very best of his potential. And still he managed to maintain that level winning another All England men singles title in 1996. 3 month later he won the Olympic men singles title in Atlanta in style: Showing a brilliant combination of excellent technique, physical strong and fast - and impressive mental appearance on court.

References

- Mikkelsen, F. 1979. Physical demands and muscle adaptation in elite badminton players. Science in Racquet Sports. Academic Publishers, Del Mar.
- Mikkelsen, F. Omosegaard, B. Frost, M. 1985. Badminton på min måde. Puls. Hørsholm.
- Omosegaard, B. 1983. Biomechanical analysis of badminton under match-like conditions. Gymnastikteoretisk Laboratorium A&B, University of Copenhagen.
- Omosegaard, B. 1991. Physiological investigations on elite and national level badminton players. Not published.
- Omosegaard, B. Fahrenholz, H. Larsson, B. Voigth, M. 1995. Physical Testing of Danish elite players during and after the Danish "Project Olympic Games 92". Not published.
- Omosegaard, Bo 1996. Physical Training for Badminton. International Badminton Federation. England.

Profile

ボ・オモセガード Bo Omosegaard



- ・デンマーク ナショナル・タレント開発マネージャー
- ・アイルランド ナショナル・コーチ 2004-2005
- ・科学修士をコペンハーゲン大学で取得
バドミントンのバイオメカニクスと運動生理学での
科学的研究
- ・デンマークの元エリート・バドミントン・プレーヤー
- ・指導歴
オリンピック バドミントン競技 金、銅メダリスト
バドミントン世界選手権 金、銀、銅メダリスト
初心者から世界的エリートレベルまでのジュニア・
プレーヤー
ヨーロッパ諸国での指導者教育システムの講師や構築
- ・著書：バドミントンに関する運動生理学の書籍を5冊
執筆
“Physical Training for Badminton” 国際バドミントン
連盟発行、最高レベルの指導者教育のためのテキ
スト
- ・数え切れないほどの国内、国際的コーチング・セミ
ナー、ワークショップ、会議の講師
- ・バドミントンの他に、ヒューマン・リソース・マ
ネージャー、ジェネラル・マネージャー、ビジネス・
マネイジメント・コンサルタント、編集主任