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Seasonal training and performance of competitive swimmers

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To determine the relationship between prescribed training and seasonal-best swimming performance, we surveyed 24 swim coaches and 185 of their age-group and open-class swimmers specializing in sprint (50 and 100 m) and middle-distance (200 and 400 m) events in a summer and winter season. We expressed effects on training as either multiples of swimmers' standard deviations (effect size, ES) or as correlations (r). Coaches prescribed higher mileage and longer repetitions of lower intensity to middle-distance swimmers than to sprinters (ES = 0.4–1.5); as competitions approached, repetition intensity and duration of rest intervals increased (ES = 0.5–0.9), whereas session and repetition distances decreased (ES = 0.4–1.3). The 95% likely ranges of the true values for these effects were about ± 0.3. Weekly mileage swum at an easy or moderate pace remained at almost 60% of the total throughout both seasons. Interval training reduced gradually from 40% of total distance in the build-up to 30% at the end of tapering. Older swimmers had shorter rests and swam more miles ($r = 0.5$–0.8). After partialling out the effects of age on performance ($r = 0.7$–0.8), better performance was significantly associated only with greater weekly mileage ($r = 0.5$–0.8) and shorter duration of rest intervals ($r = 0.6$–0.7) in middle-distance swimmers. We conclude that periodization of training and differences in training between sprint and middle-distance events were broadly in accord with principles of specificity. Strong effects of specificity on performance were not apparent, but weak effects might have been detected with a larger sample.

Keywords: coaching, questionnaire, specificity.

Introduction

Several magazines (e.g. *Swimming World and Junior Swimmer*, *Swimming Technique*, *Swimming Times*) and books (e.g. Salo, 1989; Wilke and Madsen, 1992; Gambril and Skinner, 1995) have detailed the training programmes of coaches of successful swimmers, but there are no published surveys of the training practices of swim coaches or of how those practices related to performance. Many studies of training prescription in sports other than swimming have found a positive association between performance and training distance (e.g. Foster *et al.*, 1977; Campbell, 1985; Sparling *et al.*, 1987; Marti, 1988) and higher (percent of maximum) training intensity (e.g. McKelvie *et al.*, 1985; Krebs *et al.*, 1986; Scrimgeour *et al.*, 1986; O'Toole, 1989), but only one swim study has related training behaviours to performance (Mujika *et al.*, 1995). In that study, Mujika *et al.* recorded training intensity (estimated from blood lactate concentrations), training distance (total distance swum in the season) and dryland training (stretching, weights, cords). Mean absolute training intensity for a season was the only correlate of improved performance ($r = 0.69$, $P < 0.01$). However, the authors did not relate their data to sprint or middle-distance swimmers or to a periodized model of swim training, so it is not known what components of the training programme related to different categories of swimmers at different times of the season. The aims of this study were to describe in detail the seasonal training prescription of competitive swim coaches and to relate these practices to competitive swimming performance.

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Methods

Questionnaire and participants

Self-administered questionnaires were mailed to 33 registered New Zealand swim coaches within 1 week of the end of a summer swimming season. The same questionnaires were re-administered to 25 of these coaches 6 months later at the end of a winter season. Because of the maturation of adolescents and the age at which most swimmers start to undertake substantial volumes of training, we delimited the study to the coaching practices of swimmers aged 13 years and older.

The questionnaire was developed with the aid of three local coaches. It was then piloted on 10 coaches at a national championship 3 months before the start of this study. The questionnaire was refined twice before being used for data collection; the first time was 2 months before the study began, the second 4 weeks before the study. On each of those occasions, feedback from coaches allowed unnecessary questions to be deleted and wording was altered to reflect current coaching terminology.

The questionnaire was designed to ascertain general coaching programmes and training methods. The general section included questions for coaches about their qualifications and experience, the number and competitive standard of age-group and open-class swimmers that they coached, seasonal-best performances of the 'typical' male and female sprint (50–100 m) and middle-distance (200–400 m) swimmers in their squad, and details of how they structured (periodized) their training programmes for sprint and middle-distance swimmers over the 6-month competitive season. We focused the questionnaire on the typical sprinter and middle-distance swimmer, because in our own experience and from the information we collected from piloting the questionnaire, coaches structured training programmes for groups of swimmers rather than individuals. Coaches were asked to provide details of the duration of each of four training phases for each season: build-up or conditioning, speciality, taper (including competition) and post-competition. Those coaches who prescribed more than four phases in the season were asked to group similar phases together and record the duration under what they considered was the most appropriate phase. Coaches were asked to ensure that the total duration of all phases was 26 weeks (because the summer and winter seasons were delimited by the national championships held at 6-monthly intervals).

In the training section, coaches indicated the number of sessions they prescribed for a typical week for build-up, speciality and post-competition phases. Training prescription during the taper phase varied substantially, so questions for this phase related to typical training sessions at the start, middle and end. Coaches were asked to indicate the total number of sessions for the taper phase, from which we then estimated the weekly average by dividing by the number of weeks in the taper. Coaches also estimated their average weekly distances (build-up, speciality and post-competition) and session distances (start, middle and end of taper) for intervals, hard continuous, moderate continuous and easy swimming. Weekly training distance during the taper was estimated similarly to that for the number of workouts during each week of the taper. Weekly and session training distances for each coach were weighted by phase duration before calculation of mean values for the build-up, speciality and post-competition phases. The different training distances during the taper phase were weighted by the number of total taper sessions before calculation of means for each coach.

Descriptions of typical interval sets (number of repetitions, distance, intensity and rest duration of each repetition) were also requested for each phase. Each coach was given an interval-training pace table, in which times for a given distance were converted to a pace and expressed as a percentage of seasonal-best pace for that distance. Qualitative prescription ('easy', 'moderate', 'hard' or 'race-pace') was also expressed as a percentage of seasonal-best pace on the card (Stewart and Hopkins, 1997). We used percentage of best pace for all further analyses of training intensity. To calculate the means for each measure of interval training prescription during each phase for each coach, intensity was weighted by distance (mean number of repetitions in an interval set multiplied by mean distance of each repetition), whereas interval distance and rest duration between repetitions were weighted by the number of repetitions in an interval set.

For swimmers specializing in one of the form strokes (strokes other than freestyle), the percentage of weekly training distance prescribed for all strokes during the build-up, speciality and post-competition phases was also recorded. There was insufficient space on the questionnaire to administer a similar question for the taper phase.

Correlates of swimming performance and coach qualification

Self-administered retrospective questionnaires for swimmers were also mailed out to coaches at the end of each season. These questionnaires were for swimmers to provide details of the distance group (sprint or middle-distance) in which they undertook most of their training, the specific events for which they were preparing to compete and any seasonal-best times. The times that swimmers reported were used primarily to determine the extent to which training and coaching practices related to performance. Those times were converted to a pace and expressed as a percentage of appropriate world-record pace. This procedure allowed the performance data of males and females to be combined. Each coach's qualification was recorded as an integer (5 = elite coach; 4 = level III; 3 = level II; 2 = level I; 1 = overseas, unknown NZ equivalent; 0 = no qualification) to establish relationships between coaching qualifications, coaching practices and swim performance. Coaches with a qualification from overseas were assigned, where appropriate, a value comparable to the qualification of NZ-based coaches. The mean self-reported age of swimmers training under each coach each season was calculated to determine the effects of swimmers' age on training prescription for all training phases for the summer and winter season. Similar correlates of age were determined for swimming performance at the end of each season. The mean value of each training variable of each training phase of the summer and winter season was then calculated to determine the effects of training prescription on swimming performance and coach qualification. Partial correlations were determined for these effects so that relationships between training and performance were not masked by the age of swimmers. Most of the training variables followed a non-normal distribution; therefore, for convenience, Spearman correlations were used in all these analyses. Spearman automatically performs correlations on the rank-transformed variables, which is the same as first ranking the variables, then analysing relationships using Pearson correlations (unpublished observations).

The relationship between swimmers' self-reported seasonal bests and the typical performances of swimmers cited by coaches was assessed to determine whether the use of self-reported best times was justified. This relationship was expressed as a Pearson correlation coefficient. The relationships between swimmers' age and self-reported performance, and between swimmers' age and performances reported by coaches, were also expressed as a Pearson correlation.

Validity

We conducted a validity study of the questionnaire over 6 weeks early in the build-up phase at the start of a third season. One of the authors observed a training session for each of 24 coaches, in which total session training distance and interval training prescription (repetition intensity, repetition distance and rest duration between individual repetitions) were recorded. Coaches were given up to 7 days notice that they would be observed, but they did not know the day of the visit. Similar data from the build-up phase of the third season's questionnaire were compared with the corresponding values obtained from coaches' training prescriptions during direct observation. Both of these data sets involved multiple interval workouts that were prescribed by each coach. To calculate the mean of each training variable for each coach in each data set, interval training intensity was weighted by training distance (mean number of repetitions in an interval set multiplied by mean distance of each repetition), while interval distance and rest duration were weighted by the number of repetitions in an interval set. All data relating to training distance and duration of rest intervals were then log-transformed before further analysis to reduce the effects of heteroscedasticity (the longer the interval distance or rest duration, the greater the variance) (Nevill, 1997). The means were then back-transformed. Total training distance reported for the average week in the build-up phase of the third season was divided by the number of prescribed sessions in that week to calculate the average session distance. We compared that distance with the prescribed session distance obtained during direct observation. Correlation coefficients (Pearson for repetition distance and rest duration; Spearman for session distance and interval intensity) were calculated as measures of relative validity. Paired *t*-tests (where appropriate on transformed variables) were used to determine the difference between mean values derived from questionnaires and direct observation. The magnitude of the difference was represented as an effect size.

Statistical analyses

All analyses were carried out using the Statistical Analysis System (SAS Institute, Cary, NC). Only those coaches who provided data for both seasons were included in the analyses. Data relating to coach characteristics were from the summer swimming season. Measures of centrality and dispersion used throughout are the mean and standard deviation (s).

Modelling procedures. The effects of season, specialty-distance group and training phase on coaches' training prescription were assessed with repeated-measures general linear modelling using the mixed procedure. Tests of significance of effect of training phase on training prescription were restricted to sequential training phases. Effect sizes for differences in mean values of weekly training distance, session distances and interval training data between phases, between seasons and between specialty groups were also calculated. Weekly and total session distance, repetition distance and rest duration of interval training were log-transformed before calculation of means to reduce the effects of heteroscedasticity (Nevill, 1997). Session distances for each training mode were rank-transformed before analysis because they did not follow a normal distribution and log-transformations proved impossible when coaches had values of zero. An overall (mean) measure of consistency (intraclass correlation coefficient) across training phases, seasons and specialty-distance groups was also calculated for each training variable from this analysis. The formula used was $(F-1)/(F+k-1)$, where F was the F-ratio for the coach and k was a factor representing approximately the mean number of entries per swimmer (Bartko, 1966). Intraclass correlation coefficients for the individual effects of season, training phase and specialty-distance group on only one form of training prescription (weekly distance) were also determined.

For all analyses, we chose a Type I error of 5% for declaration of statistical significance. The 95% confidence interval for no correlation (based on a sample size equivalent to the number of coaches in this study) was ± 0.40 (Fisher, 1921). We did not adjust our confidence limits so as to hold the overall Type O error rate to 5% (the chance that any true value in this study falls outside its confidence interval; Hopkins, 1997). We are of the opinion that, in publishing precision of estimates, controlling error rate is not an issue. Readers should interpret reported effects by being aware that the population value may be outside the confidence interval for some of the effects.

We interpreted correlation coefficients of the order of 0.1, 0.3 and 0.5 as thresholds for small, moderate and large effects respectively (Cohen, 1988). The 95% confidence intervals for these correlations (based on the number of coaches in this study) were –0.38 to 0.48, –0.11 to 0.62 and 0.13 to 0.75 respectively. Thus, the study had limited power to detect small and moderate relationships. The differences in means were represented as multiples of standard deviations in which we interpreted the magnitude of the effects according to the criteria of Cohen (1988): small = 0.2, moderate = 0.5 and large = 0.8.

Results

Characteristics of the participants

Twenty-five coaches (22 males, 3 females) completed and returned questionnaires at the end of the summer season (a compliance rate of 76%). One of the male coaches dropped out of the study during the winter season. Those coaches who returned a second questionnaire were aged 42 ± 11 years with 7.8 ± 6.5 years competitive swimming background and 14.0 ± 9.1 years coaching experience; 28% were coaching at national or international standard, 40% at provincial standard and 32% at club standard or acting independently. The frequencies of the qualifications of the coaches were as follows: elite coach 13%, level III coach 29%, level II coach 29%, level I 17%, other (overseas, unknown NZ equivalent) 4%, and no qualification 8%.

There were 7.7 ± 4.0 age-group and open-class swimmers in each squad that completed a questionnaire; 3.7 ± 2.8 were sprinters aged 15.3 ± 2.5 years and 5.8 ± 3.6 were middle-distance swimmers aged 14.8 ± 1.2 years. An average of 16 ± 16% of the swimmers under each coach competed at international or open national standard, 38 ± 13% at national age-group level and 46 ± 18% competed only within the province (i.e. club). Mean self-reported performances of sprinters and the typical performances reported by coaches were 75.7 ± 5.7% and 79.6 ± 4.6% respectively of world-record paces; the relationship between values reported by each coach and the mean performance of sprinters under each coach was very strong ($r = 0.81$, $P = 0.0001$). The corresponding figures for middle-distance swimmers were 78.4 ± 5.4% and 78.7 ± 3.8% ($r = 0.67$, $P = 0.002$). The correlations between the age of sprinters and self-reported bests ($r = 0.83$, $P = 0.0001$) and between a sprinter's age and typical performances reported by coaches ($r = 0.80$, $P = 0.0001$) were also very high. The corresponding figures for middle-distance swimmers were $r = 0.80$ ($P = 0.0001$) and $r = 0.37$ ($P = 0.12$).

Validity study

There were substantial differences in training prescription recorded from direct observation of sessions and that reported by coaches in their questionnaires. Repetition distance and session distance in the sprint programme were much smaller (effect size, ES, of 1.0 and 0.7 respectively) when observed than when reported. The observed duration of rest intervals for middle-distance swimmers was much greater (ES = 0.8) than that reported in questionnaires. There were small to moderate differences (ES = 0.2–0.5) between questionnaire data and corresponding observed data for all other aspects of training prescription (repetition intensity for sprint and middle-distance swimmers, repetition distance and session distance for middle-distance swimmers, and the duration of rest intervals for sprinters). The correlations between individual observed values and questionnaire values were high for repetition distance for sprinters ($r = 0.67$) and for the duration of rest intervals for the sprint ($r = 0.71$) and middle-distance ($r = 0.64$) programme. All other correlations between questionnaire data and corresponding data obtained from observations were small or insubstantial ($r < 0.2$).

Table 1. Duration of each phase of training and number of weekly training sessions prescribed by 24 coaches for sprint and middle-distance swimmers for the summer and winter seasons (mean ± *s*)

	Build-up	Speciality	Taper	Post-competition
Sprint				
Duration (weeks)	12.1 ± 3.8	7.0 ± 3.9	3.8 ± 2.2	3.1 ± 1.9
Sessions per week	6.8 ± 1.9	7.3 ± 1.9	6.6 ± 2.0	5.0 ± 1.0
Middle-distance				
Duration (weeks)	12.4 ± 4.5	7.7 ± 4.3	2.7 ± 1.4	2.8 ± 1.9
Sessions per week	7.8 ± 2.0	8.1 ± 1.7	7.3 ± 2.0	5.0 ± 1.2

Training prescription

There was little difference in any aspect of training prescription between the two seasons (data not shown). Exceptions were the prescription of less interval distance per week for sprinters during the build-up and speciality phases of winter training, and less total weekly distance for all swimmers in the winter speciality phase. The mean of the summer and winter season for each coach was used for all analyses.

There were few differences between specialty-distance groups in the duration of each training phase and number of weekly sessions per phase (Table 1). Almost half of the season was devoted to the period of build-up, followed by a gradual reduction in the duration of each phase nearing competition. It appeared that the average coach prescribed a slightly longer taper for sprinters than for middle-distance swimmers. The number of weekly sessions remained fairly constant throughout the season, with the exception of the post-competition phase. On average, middle-distance swimmers were prescribed approximately one session per week more than sprinters from build-up to competition. There was also no difference between groups in the number of rest days prescribed immediately before the most important competition of the season (sprinters, 1.5 ± 0.9 days; middle-distance swimmers, 1.3 ± 0.9 days).

There was little difference between specialty-distance groups during the build-up, speciality and post-competition phases in stroke prescription for swimmers who specialized in one of the form strokes (Table 2). Freestyle swimming dominated weekly training distance during those phases, and specialty stroke prescription made up at most one-third of total weekly training distance for the most of the season.

The upper two graphs in Fig. 1 show mean prescribed weekly and session distances for sprint and middle-distance swimmers for all coaches. The weekly distance

Table 2. Percentage of weekly training distance prescribed by 24 coaches in different phases of the summer and winter seasons for swimmers specializing in one of the three form strokes (mean ± *s*)

	Build-up	Speciality	Post-competition
Sprint			
Freestyle	59 ± 19	46 ± 18	50 ± 17
Specialty[a]	22 ± 10	36 ± 15	26 ± 15
Other[b]	19 ± 11	18 ± 9	24 ± 10
Middle-distance			
Freestyle	62 ± 15	51 ± 15	52 ± 15
Specialty[a]	20 ± 9	30 ± 10	27 ± 14
Other[b]	18 ± 12	19 ± 11	21 ± 9

[a] One of the three 'form' strokes (backstroke, breaststroke, butterfly).
[b] The other two form strokes.

in each training phase was significantly different from that in the previous phase, except between speciality and build-up and between post-competition and end of taper. The session distance in each phase of training was significantly different from the previous phase except between speciality and build-up and between start of taper and speciality. There were substantial reductions in all measures of training distance, except easy swimming, from build-up to the end of taper for both specialty-distance groups (ES = 0.4–1.3). That trend was reversed after competition (ES = 0.5–1.8). The absolute distance of easy swimming per session remained constant throughout the season and, in relative terms, actually increased from 25% of total session distance in the build-up to over 33% of total session distance by the end of taper. Interval training decreased steadily from 40% of total session distance during the build-up to 30% by the end of the season. On average, coaches prescribed slightly more than 50% of the total distance of each training session as easy or moderate-pace swimming from build-up to taper. This proportion rose to 60% during the post-competition phase.

The lower three graphs in Fig. 1 show mean prescribed intensities, distances and rest durations during interval workouts for sprint and middle-distance swimmers for all coaches. Training intensity and rest duration of interval workouts increased as competition approached (ES = 0.5–0.9). Rest duration then decreased until swimmers began to specialize again (ES = 0.6–1.0), whereas interval training intensity increased (ES = 0.9) at the start of the season after a short period of lower (ES = 2.2) intensity workouts in the post-competition phase. Repetition distance of interval training was reduced gradually throughout the season (ES = 0.6). That trend was reversed after competition (ES = 1.4).

Coaches appeared to make some modifications to their training prescription for the different specialty-distance groups. For mileage, the average coach prescribed greater weekly distance, individual session distance and session distance of moderate continuous swimming for middle-distance swimmers than sprinters (ES = 0.4–1.2). Interval workouts also varied between specialty-distance groups; on the whole, middle-distance swimmers were prescribed longer intervals of lower intensity work than sprinters (ES = 0.5–1.5).

The mean intraclass correlation coefficients (R) for all measures of training prescription across training phases, seasons and specialty-distance groups ranged from 0.08 (repetition distance during interval workouts) to 0.61 (distance of easy swimming per session). The intraclass correlation coefficients for the individual effects of training phase, season and specialty-distance group on weekly training distance ranged from 0.29 (for sprinters in the winter season) to 0.98 (for the winter season build-up).

Correlates of swimming performance

Sprint and middle-distance performance were associated with the age of the swimmers ($r = 0.66$, $P = 0.001$ and $r = 0.81$, $P = 0.0001$ respectively). Middle-distance performance was also associated with qualification of the coach ($r = 0.47$, $P = 0.03$). Among the mean measures of prescribed training for the phase and speciality-distance groups, significant positive correlates of performance for sprinters were weekly ($r = 0.56$, $P = 0.02$) and session training distance ($r = 0.60$, $P = 0.01$) during the post-competition phase, and for middle-distance swimmers were weekly training distance for build-up ($r = 0.55$, $P = 0.02$), speciality ($r = 0.76$, $P = 0.0003$), start of taper ($r = 0.56$, $P = 0.02$)

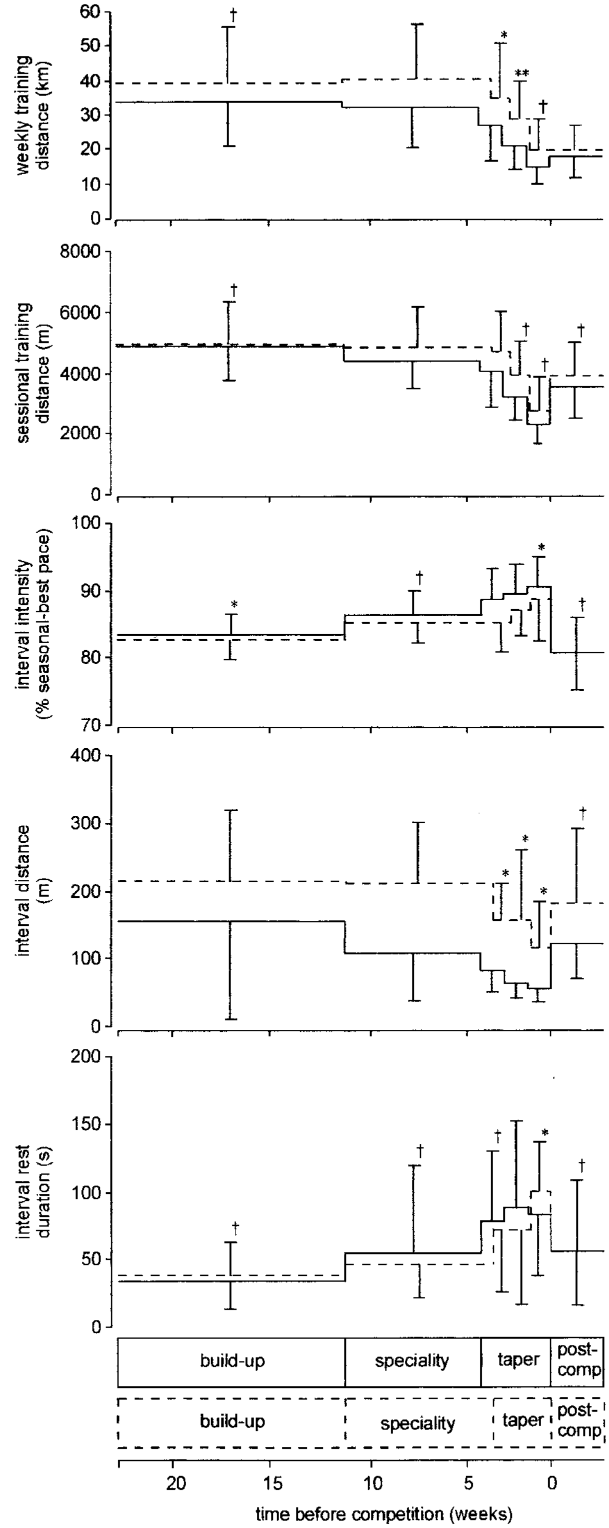

Fig. 1. Training practices prescribed by coaches for sprint (solid line) and middle-distance (dashed line) swimmers. Data are the means of the summer and winter seasons for 24 coaches. Error bars represent standard deviations. Taper was subdivided into three phases: start, middle and end. * $P < 0.05$, ** $P < 0.01$, † $P < 0.001$: significantly different from value in previous phase.

and mid-taper ($r = 0.49$, $P = 0.04$), and session training distance for build-up ($r = 0.58$, $P = 0.01$), speciality ($r = 0.75$, $P = 0.0004$) and start of taper ($r = 0.48$, $P = 0.04$). Significant negative correlations were found for middle-distance swimmers for the distance of interval training per session prescribed during the latter stages of tapering ($r = 0.48$, $P = 0.05$) and after competition ($r = 0.60$, $P = 0.02$), and for duration of rest interval in interval workouts during the build-up ($r = 0.61$, $P = 0.007$) and speciality phases ($r = 0.74$, $P = 0.0004$). The raw correlations between training and performance were slightly larger when swimmers' age was not controlled (data not shown). The duration of the build-up and number of prescribed weekly sessions in the speciality phase both correlated significantly with middle-distance performance ($r = -0.47$, $P = 0.04$ and $r = 0.62$, $P = 0.006$ respectively).

Correlates of swimmers' age

The swimmers' age had varied effects on training prescription for both specialty-distance groups in both seasons. Notable positive effects of age were found in the prescription of weekly distance during the summer build-up for the sprint and middle-distance groups ($r = 0.51$, $P = 0.03$ and $r = 0.49$, $P = 0.03$ respectively) and into the speciality phase for the middle-distance group only ($r = 0.57$, $P = 0.01$). The age of the swimmers was also positively correlated with the prescription of weekly distance for middle-distance events during the winter build-up ($r = 0.58$, $P = 0.02$). Other significant positive correlations were noted in the middle-distance group for the distance of interval training for most of the summer season ($r = 0.55$, $P = 0.01$ and $r = 0.66$, $P = 0.002$ for build-up and speciality respectively) and for the distance of easy swimming in the build-up ($r = 0.67$, $P = 0.006$) and immediately before competition ($r = 0.52$, $P = 0.04$) in the winter season. Notable negative effects of age were found in the winter programme for the middle-distance group in the prescription of hard continuous workouts leading up to and immediately after competition ($r = -0.55$, $P = 0.03$ and $r = -0.75$, $P = 0.007$ respectively), easy swimming in the speciality phase ($r = -0.64$, $P = 0.01$) and for duration of rest intervals for most of the season (build-up: $r = -0.67$, $P = 0.007$; start of taper: $r = -0.64$, $P = 0.009$; middle of taper: $r = -0.75$, $P = 0.001$).

Correlates of coach's qualification

More-qualified coaches prescribed greater weekly and session training distance during the speciality phase ($r = 0.65$, $P = 0.004$ and $r = 0.48$, $P = 0.04$ respectively) and larger weekly training distance midway through the taper ($r = 0.50$, $P = 0.03$) for middle-distance swimmers. The more-qualified coaches also prescribed a larger training distance for a single session during the build-up ($r = 0.45$, $P = 0.05$), greater weekly and session training distance during the speciality phase ($r = 0.56$, $P = 0.01$ and $r = 0.60$, $P = 0.006$ respectively) and larger weekly training distance midway through the taper ($r = 0.52$, $P = 0.02$) for sprinters. The only significant correlate of any of the interval training prescriptions with coach's qualification was a lower intensity for sprinters at the end of the taper ($r = -0.49$, $P = 0.03$). None of the correlations of coach qualification with any of the prescribed session training distances for intervals, hard and moderate continuous, and easy swimming during any phase of training were significant (data not shown). The more-qualified coaches prescribed longer duration build-up and speciality phases ($r = 0.46$, $P = 0.04$ and $r = 0.51$, $P = 0.02$) for middle-distance swimmers. A greater number of training sessions per week during the speciality phase for middle-distance swimmers was associated with more-qualified coaches ($r = 0.67$, $P = 0.002$). The more-qualified coaches also prescribed less days of rest for middle-distance swimmers before a major competition ($r = -0.56$, $P = 0.02$). There was a tendency for the more-qualified coaches to prescribe a lower training intensity for sprinters for most of the season (build-up and speciality), but none of the correlations were significant ($r = -0.38$ to -0.40, $P > 0.05$).

Discussion

This study of seasonal training practices of coaches of competitive swimmers has produced novel data on two important aspects of swim training: seasonal, periodized prescriptions for sprint and middle-distance swimmers and the strength of the relationships between training and performance. These aspects are discussed below after a discussion of the validity of the questionnaire data.

Validity

The magnitude of a relationship (e.g. correlation coefficient or change in means) is degraded by a factor equal to the product of the validity correlation coefficients (Kupper, 1984). For example, if the validity correlations (r) of two variables x and y are each 0.70, then the observed correlation between x and y will be only 0.49 of the true correlation. Clearly, then, the variables in this study with low validity correlations would have prevented us observing some of the weaker relationships between variables.

Session distance and interval training data obtained by direct observation of training prescription indicated generally low validity for corresponding data supplied by coaches in their questionnaires. Total session distance is normally fairly stable within a given phase, except the taper (personal observation), so we expected to find high validity for this measure of training prescription. However, it is possible that the total distance recorded on the day of observation was for a 'one-off' session. By observing more sessions, we may have been able to show whether such a possibility occurred, but that method was considered impractical and too costly for this study. In contrast to the total session distance being normally stable, the workouts within a session do vary on a daily basis (personal observation). Hence, low validity for reported interval data may not be as poor as it appears. In the questionnaire, coaches provided details of three typical interval sets that they prescribed in the build-up, but these sets may not have been prescribed on the day of observation. The description of a greater number of typical interval sets may have produced questionnaire data of greater validity, but that option was not possible, owing to limited space on the questionnaire.

Training prescription

The number of prescribed weekly swim sessions in each phase appears to indicate that swimmers performed one workout most days of the week. However, it is common practice for coaches to prescribe at least one rest day each week, so it is likely that two workouts per day was the norm for most days. Such a practice is almost institutionalized within swimming, even though there is good evidence that double-swim workouts have no greater benefit to performance than a single daily session (Costill *et al.*, 1991).

The small sample size in this study limited the ability to detect small differences in training between training phases, between specialty-distance groups and between seasons. Nevertheless, trends in the data indicated coaches did make allowances in their prescriptions, particularly between phases, where there was a general increase in training intensity and rest duration as the season progressed, whereas distance was reduced. Differences between specialty-distance groups were also apparent: middle-distance swimmers were prescribed greater mileage and longer repetitions of lower intensity than sprinters. Apart from a slight reduction in distance in winter, there was little difference in training prescription between seasons.

There were substantial differences in mean training prescription between phases and between specialty-distance groups, but the generally low intraclass correlation coefficients indicated that the pattern of change of training prescription between coaches was not consistent. In other words, if coaches were to be placed in rank order for a particular aspect of training for a phase of training or specialty-distance group, the order would change considerably for a different phase or for a different distance group. Exceptions to poor consistency were for weekly training distance for the winter season build-up, summer season post-competition and middle-distance swimmers in the speciality phase ($R = 0.98$, 0.97 and 0.93 respectively).

The average training plan in the present study reflected principles of specificity more during taper than during build-up and speciality. Throughout the build-up, workouts consisted mostly of continuous and easy swimming. Only about 40% of the total distance was prescribed as interval workouts in that phase, and the absolute and relative (percent of total) distance of interval training decreased gradually from early season to the end of taper. Also, the average intensity of interval training during all phases was substantially lower than that in competition, and easy and moderate-pace swimming accounted for more than half of the total distance in all phases of training. It should also be noted that freestyle dominated training prescription for most of the season for swimmers specializing in one of the form strokes. Taken together, these prescriptions indicate a substantial proportion of what some coaches refer to as 'filler mileage' (non-specific, easy to moderate-pace swimming to make up the target distance for the session). In our experience, coaches believe that such prescription plays multiple roles: to act as a base for more intense training as competition approaches, to concentrate on technique, to avoid overtraining and to assist in recovery from hard workouts during the season and between swims during competition. Controlled scientific investigations would be required to determine the extent to which these roles impact on performance.

Up to 2 weeks of overload before the taper may enhance performance (Bannister, 1991; Morton, 1991; Lehmann *et al.*, 1992; Bruin *et al.*, 1994; Mujika *et al.*, 1996). During the overload, athletes increasingly overreach to such an extent that, within 10–14 days, they start to show signs of chronic overtraining (Costill *et al.*, 1988a,b; Kirwan *et al.*, 1988; Barr *et al.*, 1991). Throughout the taper, athletes then recover from the fatigue of the overload, while positive adaptations from overload lead to a supercompensation effect that results in enhanced performance (Harre, 1973; Viru, 1984). There was a relatively long speciality phase in the present study (7–8 weeks), so on the one hand we could conclude that overloading probably did not form part of the coaches' periodized training programmes. On the other hand, it is possible that a brief period of overload was indeed prescribed, but that we missed the details of that phase because coaches had to describe training in only four phases in the questionnaire. Future investigation of coaches' periodized plans should be designed to assay greater detail in training prescription than we were able to in the present study.

Training during the taper was at its most specific for the season, when coaches prescribed a period of around 7–21 days, with one or two rest days before competition. Such prescription appeared to be in line with the results of previous studies (e.g. Houmard *et al.*, 1989, 1990; Johns *et al.*, 1992; Shepley *et al.*, 1992; Houmard and Johns, 1994). During this period, distance decreased gradually as suggested by Costill (1985), Morton *et al.* (1990) and Morton (1991), and training intensity remained high as suggested by Neary *et al.* (1992), Shepley *et al.* (1992), Hopkins (1993), Gibala *et al.* (1994), Houmard *et al.* (1994) and Martin *et al.* (1994). Apparently, such changes in training allow time to recover from the physical stress (Bannister *et al.*, 1975; Calvert *et al.*, 1976; Costill *et al.*, 1985a,b; Morton *et al.*, 1990; Bannister, 1991; Morton, 1991) and mental stress (Ripol, 1993) of previous training.

Post-competition training was a short period of relatively low mileage and intensity. During this phase, easy and moderate-pace swimming made up even more of the total proportion of session distance. However, it is likely that swimmers would have obtained a large training effect from competing in multiple events (which may include heats, semi-finals and finals). Thus, a period of long, slow distance training after competition appears appropriate to recuperate before hard training can begin again in the build-up.

The age of swimmers also appeared to have some effect on training prescription, with older middle-distance swimmers being prescribed a greater distance of interval training in the summer speciality phase, while winter training involved a greater distance of easy swimming in the build-up, reduced intervals for most of the season and less hard continuous workouts after competition. Although most other correlations between swimmers' age and training prescription were small, the possibility remains of a substantial effect of age on training practices. A larger sample size would be required to detect such effects.

Correlates of swimming performance

Very high correlations between a swimmer's self-reported performances and the performance of the typical swimmer reported by coaches justified our decision to use self-reported bests. At first sight, these reported bests suggest swimmers of low ability. However, most of the swimmers in this study were age-group competitors and the world records were for open-class swimmers.

The small sample size in this study also prevented the detection of small and moderate correlations between training prescription and swimming performance. There were some strong correlations, mainly for middle-distance swimmers (weekly training distance and total session distance during the speciality phase, and interval rest duration during the build-up and speciality phase), but training prescription on the whole appeared to have little impact on performance (the relationship between training and performance was attenuated only slightly when controlling for the effect of swimmers' age). The better middle-distance swimmers were prescribed a greater total training distance (weekly and session) from build-up to the start of taper and a greater weekly training distance midway through the taper. Immediately before competition, these same swimmers were prescribed less interval training. Furthermore, training intensity had no significant association on middle-distance or sprint performance. These findings, coupled to the prescription of shorter rest intervals during interval workouts for most of the season (build-up and speciality), indicated that coaches of the faster middle-distance swimmers were inclined to prescribe less-specific training more akin to the long, slow distance method. One interpretation of these results is that long, slow distance training enhances middle-distance performance. Alternatively, owing to the longer time that better swimmers devote to training, coaches may tend to adopt long, slow distance training for these swimmers to prevent overtraining. Controlled trials are required to determine whether middle-distance and sprint performance is enhanced more by long, slow distance training than by training that is more specific to the paces and durations involved in competition.

Previous studies have reported high positive correlations between performance and training distance (e.g. Slovic, 1977; Gullstrand and Holmer, 1982; Dotan *et al.*, 1983; Ekstrand *et al.*, 1983; Bale *et al.*, 1985; Marti *et al.*, 1988) and higher (percent of maximum) training intensity (e.g. Hagan *et al.*, 1981; Linetz *et al.*, 1981; Foster, 1983; Bale *et al.*, 1986; Mujika *et al.*, 1995). The results of the present study are consistent with the relationship between training distance and performance found in past studies, but it appears that the intensity of workouts did not have the same impact on swimming performance as that found previously.

Correlates of coach qualification

Long, slow distance training seemed to be a favourite of the more-qualified coaches. A lower intensity of training for sprinters was also a trend of more-qualified coaches, but training intensity of middle-distance swimmers did not appear to be affected by coach qualification. The completion of coaching courses had few other effects on the way coaches prescribed their training. The more-qualified coaches did have faster middle-distance swimmers, but this relationship might have been due to migration of better swimmers to these coaches rather than to an effect of qualifications on performance. Thus, the more-qualified coaches did not necessarily produce the better swimmers.

In conclusion, this study has documented the seasonal, periodized training of competitive swimmers and how training practices relate to performance. Differences in training prescription between specialty-distance groups and between phases of training were broadly in accord with principles of specificity. Seasonal periodized training was characterized by non-specific workouts at the beginning of the season and more race-specific training as competition approached. The lack of a relationship between swimmers' age and training prescription suggests that coaches grouped swimmers of similar ability, regardless of age. Finally, there may have been small effects of training durations or intensities on swimming performance that we did not detect, but it is reasonably clear that there were no large effects. Coaches and swimmers should therefore not expect major changes in performance from anything other than major changes in these aspects of training.

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