JOURNAL OF APPLIED SPORT PSYCHOLOGY, 17: 64–78, 2005

ISSN: 1041-3200 print / 1533-1571 online
DOI: 10.1080/10413200590907577

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Expertise in Ultra-Endurance Triathletes Early Sport Involvement, Training Structure, and the Theory of Deliberate Practice

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The theory of deliberate practice (Ericsson, Krampe, & Tesch-Römer, 1993) is predicated on the concept that the engagement in specific forms of practice is necessary for the attainment of expertise. The purpose of this paper was to examine the quantity and type of training performed by expert UE triathletes. Twenty-eight UE triathletes were stratified into expert, middle of the pack, and back of the pack groups based on previous finishing times. All participants provided detailed information regarding their involvement in sports in general and the three triathlon sports in particular. Results illustrated that experts performed more training than non-experts but that the relationship between training and performance was not monotonic as suggested by Ericsson et al. Further, experts' training was designed so periods of high training stress were followed by periods of low stress. However, early specialization was not a requirement for expertise. This work indicates that the theory of deliberate practice does not fully explain expertise development in UE triathlon.

Participation in ultra-endurance (UE) triathlons has continued to increase since their inception in the late 1970s. Although beginning as a single event designed to test the limits of human endurance and persistence, UE triathlon competition now includes over a dozen events worldwide completed by athletes of all ages and from all walks of life. Sport scientists (e.g., O'Toole, Douglas, & Hiller, 1989; Speechly, Taylor, & Rogers, 1996) have indicated several factors that contribute to success in UE triathlon performance; however, we have no insight on the forms and quantities of practice that influence how UE triathletes develop.

Researchers studying the stages of expertise development have provided a number of models to explain the progression from novice to expert. For instance, Bloom (1985) examined expert development in fields ranging from mathematics to swimming and observed that individuals

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Received 27 March 2003; accepted 15 December 2003.

The authors would like to thank the following individuals and groups for their support in the completion of this study: Barrie Shepley, Peak Centre for Human Performance, and Endurosport. Appreciation is also extended to the triathletes who took part in the data collection. Support for this study was given by a doctoral fellowship from the Social Sciences and Humanities Research Council of Canada (SSHRC Fellowship # 752-2001–1491) and an equipment grant from Computrainer Inc (Seattle, WA) to the first author. Partial support was also provided by a standard research grant from the Social Sciences and Humanities Research Council of Canada (SSHRC Grant # 410-2002-0325) to the second and third authors. The second and third authors had equal contributions to this research project. The authors would also like to acknowledge Janet Starkes and two anonymous reviewers for valuable comments on an earlier version of this paper.

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pass through three qualitatively different stages on their way to becoming an expert performer. These were categorized as the early years, the middle years, and the later years. Côté and colleagues (Côté, 1999; Côté, Baker, & Abernethy, 2003) extended Bloom's work by examining the range and sequence of sport-related activities experts experience during their development. Their investigations revealed that athletes pass through three stages of sport participation prior to the attainment of expert level performance (i.e., sampling years, specializing years, and investment years). During these stages significant changes occur in several areas. There is a shift from activities that are play-like in nature to more structured and effortful training activities. In addition, the number of sport-specific training hours dramatically increases from initial involvement in the sampling years to committed involvement in the investment years (Baker, Côté, & Abernethy, 2003). Researchers consistently report differences in the amount of sport-specific training between expert and non-experts during later stages of development (e.g., Helsen, Starkes, & Hodges, 1998; Hodges & Starkes, 1996).

The theory of deliberate practice, articulated by Ericsson, Krampe, and Tesch-Römer (1993), is predicated on the concept that it is not simply training of any type, but the engagement in specific forms of practice, that is necessary for the attainment of expertise. Training activities that fall within the definition of deliberate practice include activities undertaken to develop required capacities that are not the most enjoyable activities to perform, require effort and concentration, and do not lead to immediate social or financial rewards. Central to the notion of deliberate practice is the *monotonic benefits assumption*. Ericsson et al. (1993) observed that a monotonic relationship existed between the number of hours of deliberate practice and the performance level achieved among pianists and violinists. Researchers examining the application of the theory of deliberate practice to sport (e.g., Baker et al., 2003; Hodge & Deakin, 1998; Starkes, Deakin, Allard, Hodges, & Hayes, 1996) have generally supported the strong positive relationship between hours of high quality training and ultimate achievement. However, an important distinction should be made about the activities that constituted deliberate practice in these studies. Sport studies consistently report positive correlations between relevance, effort, and enjoyment (e.g., Starkes et al., 1996). As a consequence, all sport-specific training has been considered as deliberate practice for the purpose of cross discipline comparisons, whereas in the Ericsson et al. (1993) study only hours spent practicing alone were considered as deliberate practice.

While sport researchers have provided strong support for the basic premise of the theory of deliberate practice, that is, the positive relationship between training and expertise, other aspects of the theory remain unproven. For instance, the theory of deliberate practice is grounded in the notion that specializing in a single sport during early stages of development is superior to more diversified types of involvement. However, researchers examining the early stages of development in elite athletes (e.g., Carlson, 1988; Côté, 1999; Hill, 1993) have reported that early specialization as a child does not seem to be an essential ingredient for exceptional sport performance as an adult. In a recent study of expert decision-makers in basketball, netball, and field hockey, Baker et al. (2003) proposed that participation in other relevant activities (e.g., other sports where dynamic decision-making is necessary) during early phases of development augmented the physical and cognitive skills necessary in their primary sport. An examination of elite field hockey, rugby and water polo players by Stevenson (1990) also suggested that those who have a diversified early involvement were not disadvantaged. Furthermore, Barynina and Vaitsekhovskii's (1992) reported that elite swimmers who specialized early spent less time on the national team and ended their sports careers earlier than athletes who specialized later.

Another aspect of the theory of deliberate practice that remains unclear is the idea that expert performers are superior to non-experts in managing training effort. According to Ericsson et al.

(1993) a key constraint to the accumulation of adequate amounts of deliberate practice is a balance between intense effort and recovery. Participation in deliberate practice is physically and mentally demanding and, therefore, adequate periods of recovery are required to prevent physical exhaustion as well as mental staleness, burnout, or motivation problems (Gould & Dieffenbach, 2002). Although the amount of training may be a better predictor of performance, proper scheduling of training intensities is crucial to laying the groundwork for progressive increases in training distances without the occurrence of injury or other setbacks such as burnout and staleness (Kellmann, 2002).

In the past two decades the concept of periodization has become the principal model for managing training stress and recovery in sport. Periodization is defined as the "organization of a training year into different periods to attain different objectives" (Kent, 1994, p. 329). The purpose of designing training programs in this manner is to allow the athlete to attend to useful training objectives during early periods of the training year while maintaining an optimal level of readiness during the competitive season. Fry, Morton, and Keast (1991, 1992) presented a model of periodized training grounded in the notion that periods of high training stress should be alternated with periods of relatively low stress to allow for maximal physiological adaptation with minimal risk of overtraining or overuse injuries. The periodization model divides an athlete's training year into phases of training emphasis called "macrocycles." The length of each macrocycle varies with recovery cycles (i.e., the "off-season") typically being the shortest and preparatory cycles being the longest. Within each macrocycle are "mezocycles," each made up of 4 weeks of training. Each week of training makes up a "microcycle." The underlying principle of the periodization model is that cycles of very high training intensity are followed by cycles of reduced intensity, thereby controlling training stress.

The notion of dividing training years into specific phases was derived from Selye's (1976) *General Adaptation Syndrome*. Selye's research is based on the concept that the body has a three-stage response to stress (shock, adaptation, and staleness) and these three stages have been adapted to describe the developmental processes associated with physical training and sport involvement (e.g., Fleck & Kraemer, 1987). Periodization of training is intended to prevent athletes from reaching or spending too much time in the third stage (staleness) by varying training schedules so that new training stimuli are presented at the end of the adaptation phase. If the time between when adaptation occurs and new training stress levels are introduced is too long, maximal training effects are compromised. On the other hand, if the time is too short, coaches and athletes run the risk of incurring injuries or overtraining syndrome (Fry et al., 1991, 1992; Gould & Dieffenbach, 2002).

Ultra-endurance (UE) triathletes provide an exceptional group with which to investigate the theory of deliberate practice since athletes must balance large amounts of training in three different sports in order to compete in this demanding event. Several studies (e.g., Gulbin & Gaffney, 1999; O'Toole, 1989) have illustrated that UE triathletes perform extraordinary amounts of training during a typical week. Additionally, expert triathletes perform higher amounts of training per week (Holly, Barnard, Rosenthal, Applegate, and Pritikin, 1986) than non-experts. However, our understanding of how expert UE triathletes develop is limited.

This study examined the applicability of the theory of deliberate practice to expertise in UE triathlon. There were two main purposes of the present study. The first was to examine whether a stable participation pattern emerges across sports and the extent to which participation in other sport activities influences successful participation in UE triathlon. The second was to examine the yearly training of expert and non-expert UE triathletes to determine if differences exist between these groups in the way they structure their training. It is anticipated that experts training will be different from the non-expert groups in the amount of training performed and the way in which this training is structured.

METHOD

Sample

Participants in this study were 28 male ultra-endurance triathletes. Experts ($n = 9$) were identified as being the highest-placing Canadian athletes in 'Ironman' distance races. Triathletes were identified as experts if their finishing times (mean finishing time 9 hours 21 minutes) were two standard deviations above the mean finishing time for their population (i.e., males 25–40 years of age). The list of expert athletes was verified by the head coach of the Canadian National Triathlon Team. The mean age for this group was 31.3 years ($SD = 3.1$). They had been competing in triathlons for an average of 11 years ($SD = 4.4$) and Ironman triathlons for an average of 5.0 years ($SD = 2.3$). Expert athletes had completed an average of 6 ($SD = 1.9$) Ironman distance races at the time of data collection.

Two additional groups were created to provide comparative data. A 'middle of the pack' group (Mid-pack, $n = 9$) was selected by choosing athletes with finishing times around the mean for all individuals in their age range (mean finishing time 12 hours 2 minutes). The mean age for the Mid-pack athletes was 32.3 years ($SD = 3.4$). They had been competing in triathlons for an average of 7.7 years ($SD = 3.6$) and Ironman triathlons for an average of 3.2 years ($SD = 2.6$). Mid-pack athletes had completed an average of 2.6 ($SD = 1.4$) Ironman distance races at the time of data collection.

A 'back of the pack' group (Back-pack, $n = 9$) was selected from athletes with finishing times of greater than two standard deviations from the population mean (mean finishing time 15 hours 3 minutes). The mean age for the Back-pack athletes was 33.8 years ($SD = 4.4$). They had been competing in triathlons for an average of 5.0 years ($SD = 2.1$) and Ironman triathlons for an average of 2.5 years ($SD = 0.7$). Back-pack athletes had completed an average of 2.6 ($SD = 0.7$) Ironman distance races at the time of data collection.

Data Collection Interviews

Each participant completed an adaptation of a structured retrospective interview specifically developed to examine the content and quantity of early sport involvement and practice activities of elite athletes (Côté, Ericsson, & Beamer, in press). Interviews were conducted one-on-one in a quiet environment with each interview lasting between 2 and 3 hours. The type and duration of activities that participants engaged in throughout their development was recorded using standardized forms. The initial section of the interview was devoted to the establishment of a comprehensive set of organized sports undertaken by the athlete. Athletes provided an average of the hours per week and months per year of involvement for all sports they were involved in throughout their development. The specific instructional set used to elicit information from the athlete was:

> I would like to focus on the sports that you were involved in when you were young. I would like you to list your early sport involvement outside of mandatory school activities. Looking back over your entire life please tell me of any type of sports that you engaged in on a regular basis before you decided to specialize in triathlon. How old were you when you first got started? How long have you kept up the involvement? Please tell me about any periods when your involvement was stopped. For each of the activities that you have provided, can you recall the number of hours per week and months per year you were regularly involved?

The second section of the interview assessed the amount of time participants spent in swimming, cycling, and running. Each sport was examined separately and athletes provided the number of hours per week and number of months per year that they were involved. The following instructional set was used to elicit this information:

> For each of the years listed in the chart can you provide the number of hours per week and number of months per year that you were involved in swimming (or cycling or running)? This includes competitive events and specific training activities for your sport (e.g., organized training, competitions, self-initiated training, and individualized instruction).

All swim, cycle, and run training was termed ‘triathlon-specific training.’

Training Structure Information

Participants also completed two charts detailing their training during a one month and 12 month period. In the one month chart, athletes described the month of training that occurred two months prior to their key UE triathlon of the season. For example, if an athlete was focusing on a race on August 31 training information for July would be described. Athletes provided information regarding the type and duration of all workouts. Further, athletes provided a rating of training effort by estimating which heart-rate zone they were working at during the workout.[1] Athletes chose from five heart rate zones (Zone 1 = 50–60% maximum heart rate; Zone 2 = 60–70%; Zone 3 = 70–80%; Zone 4 = 80–90%; Zone 5 = 90–100%). Participants also used this intensity framework to estimate training effort for the 12-month chart. In this chart athletes included information about the number of hours of training per week and the estimated percentage of weekly training time spent in each of the five zones.

Standardizing Training Time

A benefit to examining activities that are similar in their performance requirements is that overall training effort can be easily examined by quantifying various forms and intensities of training into standardized units. Using a modification of a procedure developed by Morton, Fitz-Clarke, and Banister (1990; see also Rowbottom, Keast, Garcia-Webb, & Morton, 1997), training time in each of the triathlon disciplines was converted into standardized training units (T_U) based on the duration and intensity of the activity performed. A T_U is made up of the product of the duration (time in minutes) and a weighting of intensity. The intensity weightings were created from an equation presented by Morton et al. (1990) as a means of quantifying physical intensity. In this equation, heart rates during a training session were compared with the athlete's maximal heart rate to attain a measure of how hard the athlete *worked* compared to how hard they *could have worked* (*the* Δ*HR ratio*). Using this method, any form of aerobic training could be quantified using the following equation: $T_U = D * (HRex\text{-}HRrest)/(HRmax\text{-}HRrest)$ or $D * \Delta HR\ ratio$, where *D* is duration of the activity, *HRex* is the heart rate during exercise, *HRrest* is the athlete's resting heart rate, *HRmax* is the athlete's maximum heart rate, and the Δ*HR ratio* refers to the relationship between exercise heart rate and maximum heart rate.

Statistical Analyses

Career involvement in swimming, cycling, running, and other sports was examined using analyses of variance (ANOVA). Two-way ANOVAs (Group × Event) were used to examine differences among the groups' involvement in triathlon training or swimming, cycling, and

[1]These five training zones represent a conventional rating of training intensity that the athletes were familiar with and used as part of their training regimen.

running individually. Involvement in swimming, cycling, and running in the three groups across time was examined using a three-way (Group × Event × Year) repeated measures ANOVA. Training involvement across the 12-month period was examined using a method outlined by Kleinbaum and Kupper (1978) that compared the regression lines for the three groups. Total training units performed during the 12-month period was investigated using univariate ANOVA. Training for each group during the one-week cycles (i.e., microcycles) was examined via a time series analysis using auto correlation (Box & Jenkins, 1976). This procedure was designed to detect non-randomness in data by examining trends in the data over time. The auto correlation compares values in a series, in this case a group's microcycle data, to those same values a set time interval later (known as a 'lag'—in this case 1 day later). For all ANOVAs, significant effects were identified using Scheffé post hoc procedures and effect size (ES) was identified using partial Eta squared. Statistical significance was determined using adjusted alpha levels according to Bonferroni's method (0.05 divided by the number of comparisons). Homogeneity of variance was examined using Levene's test and results indicated a violation of the homogeneity of variance assumption on only one analysis (for the age at which the groups began training), therefore no data transformations were performed.

RESULTS

Validity of Retrospective Recall Information

Establishing the validity of data collected using retrospective recall is often problematic. One of the advantages of using triathletes as a study population is that they typically possess detailed training diaries covering years or even decades of involvement. A subsample of triathletes ($n = 12$) had kept detailed training diaries during their careers (range 2–7 years) and made these diaries available for the purpose of checking the validity of the information provided during the interview. To this end, the total number of hours reported per year in the interview was compared to the corresponding year in the athletes' training diaries. Results indicated a moderately high correlation ($r = .72$) and a reasonable percent agreement (70%) between these two sources of triathlon training hours.

Reliability of the 12-month and one-month training charts were confirmed using two methods. The first used a built in redundancy to check the reliability of information regarding the number of training hours. Specifically, the information provided by the athletes in the training charts profiling their monthly and yearly training plans was compared (i.e., total hours in the one month chart was compared to the corresponding month in the 12-month chart). The correlation indicated a high degree of reliability ($r = .77$) and the percent agreement between the information in these two training forms was 89%. The second method compared the total hours of training provided in the training forms to the total number of hours recorded in the athletes' training logs. Results indicated a high correlation ($r = .86$) and a high percent agreement (81%) between these two sources of training information. These examinations indicate that the data were reasonably reliable and valid.

Involvement in Swimming, Cycling, and Running

For each group, the sequence from beginning endurance sport participant to UE triathlete usually started with running. The Expert group began running at 14.3 years on average and the Mid-pack and Back-pack athletes began at 19.7 and 23.2 years of age respectively. Running was followed by the addition of swimming (mean starting age 18.4, 18.1, and 23.4 years for Experts, Mid-pack and Back-pack triathletes respectively), cycling (18.6, 21.3, and 26.7 years of age respectively) and short course triathlon competition (19.0, 23.7, and 29.1 years

Table 1
Descriptive Statistics for Accumulated Hours in Swimming, Cycling, Running, and Other Sports for Each Group (Standard Deviation in Parenthesis)

	Experts	Mid-pack	Back-pack
Hours Prior to Beginning Triathlon			
Hours Swimming	242.3 (692.8)	1128.0 (3161.7)	160.4 (296.8)
Range	0–2088	0–9552	0–936
Hours Cycling	210.7 (520.1)	185.6 (222.8)	527.1 (788.3)
Range	0–1576	0–576	0–1934
Hours Running	594.8 (967.3)	697.8 (1099.8)	778.0 (1079.1)
Range	0–2976	0–3240	0–3048
Hours Other[a]	5517.9 (3956.7)	5480.4 (3659.4)	3454.5 (4146.8)
Range	2050–12092	1296–12724	0–11016
Total Hours to Date[b]			
Hours Swimming	3472.7 (1188.3)	2034.7 (3148.6)	653.8 (580.0)
Range	1320–5192	358–10272	172–2160
Hours Cycling	5038.8 (1831.2)	2065.4 (1413.1)	1725.1 (1485.8)
Range	2534–8008	624–5208	528–5208
Hours Running	3457.3 (1461.9)	2095.7 (1311.2)	1743.8 (1080.0)
Range	1512–5664	408–4140	672–4008
Hours Triathlon[c]	12557.9 (3581.0)	6195.8 (3424.5)	4122.7 (2288.3)
Range	8004–19630	1390–12984	2188–9912
Hours Other[a]	8787.1 (3193.4)	5603.3 (4139.6)	4313.6 (4388.3)
Range	4896–12860	792–11968	292–11280

[a]Hours Other is made up of the total hours spent in other sports minus time spent in swimming, cycling and running.
[b]Total Hours to Date includes training hours as a triathlete as well as the hours accumulated prior to beginning triathlon.
[c]Hours Triathlon is made up of the cumulative hours of training in swimming, cycling, and running.

of age respectively). After a period of time competing in short course events athletes began competition in UE triathlon events (25.2, 29.3, and 31.9 years of age respectively). Main effects were found for group $F\ (2, 25) = 7.70$, $p < .01$ (ES = .38) and for event $F(4, 100) = 18.11$, $p < .001$ (ES = .42). Experts began involvement in the training activities significantly earlier than Back-pack athletes. Although the data for the Mid-pack group typically fell between the Expert and Back-pack groups, there were no statistically significant differences between the mid-pack athletes and the other two groups. Across the different events, training for triathlon in general usually occurred later than swimming and running training and training for UE triathlon occurred later than all other events (i.e., swimming, cycling, running, and triathlon in general).

Table 1 presents the hours spent in swimming, cycling, and running *prior to beginning* participation in triathlon competition and the *total accumulated hours* spent in swimming, cycling, running, and triathlon training at the day of data collection. Examination of the standard deviations and the range of responses indicate a significant degree of variation within the groups. There were no significant differences among the groups in time spent in swimming, cycling, and running prior to beginning triathlon, although, the participants generally spent more time running than swimming and cycling prior to becoming a triathlete.[2] Examination

[2]The one exception is in the mid-pack group which reported a high level of swim training prior to beginning triathlon but is likely due to the inclusion of a near elite level swimmer who performed over 10 000 hours of swim training.

of the total hours accumulated at the time of data collection revealed a main effect for group $F(2, 25) = 19.90$, $p < .001$ (ES = .60). Experts had greater training than Mid- and Back-pack triathletes. There were no significant differences between the Mid-pack and Back-pack groups.

Hours of triathlon-specific training per year (i.e., the sum of hours in swimming, cycling, and running each year) in the groups of triathletes were examined for the first five years of involvement. Due to limited experience in the Back-pack group, analyses beyond five years of involvement were not possible. Expert triathletes clearly increased their average training hours each year while Mid-pack and Back-pack triathletes only increased their training hours to a small extent. Analyses of the data revealed main effects for group $F(2, 25) = 8.86$, $p < .01$ (ES = .48) and year of involvement $F(4, 100) = 9.10$, $p < .01$ (ES = .33). The interaction was not significant ($p = .08$). Across skill level, Experts' yearly training hours were significantly higher than the Mid-pack and Back-pack groups.

Separate examinations were conducted for hours spent in swimming, cycling, and running and main effects were found for Group, $F(2, 25) = 7.30$, $p < .01$ (ES = .37); Event, $F(2, 50) = 6.78$, $p < .01$ (ES = .21); and Year, $F(4, 100) = 7.25$, $p < .001$ (ES = .22). In addition, there were significant interactions for Group × Year $F(8, 100) = 2.27$, $p < .05$ (ES = .15) and Event × Year $F(8, 100) = 2.34$, $p < .05$ (ES = .09). The Group × Year interaction indicated that experts increased their training each year while mid-pack and back-pack athletes remained relatively stable. The Event × Year interaction indicated that while all forms of training generally increased across the years, this increase was more pronounced in cycling.

Early Sport Involvement

In addition to the triathlon-specific training hours, measures were computed that indicated the hours of participation in other sports prior to beginning triathlon and total hours in other sports to date (Table 1). No significant differences existed among the groups for these measures.

Differences in Training Output

The 12-month and one-month training profiles were examined several ways; annual, one-month (i.e., mesocycle), and one-week (i.e., microcycle) training outputs were compared.

Annual Training Output

Figure 1 presents the T_Us for each week of training in the 12 months leading up to a key UE triathlon. Experts completed greater amounts of training throughout the year with the exception of a two-week period in the 41st and 42nd weeks of training. In addition, the Expert triathletes generally followed the concept of periodization by having weeks of high intensity followed by weeks of reduced intensity. Mid- and Back-pack triathletes were undifferentiated and had linear increases in training throughout the year without the periods of reduced intensity. All groups displayed a decrease in training during the period 6–8 weeks from the key race followed by a build-up phase and a gradual taper into the competition. Analyses indicated that the Experts were significantly different from the Mid-pack and Back-pack groups (F for line coincidence $= 142.48$, $p < .001$, and 135.32 $p < .001$, respectively) but that there were no differences between the yearly training of the two non-expert groups.

Total T_Us for the 12-month period were calculated. Experts performed an average of 29879 training units during this period while the Mid-pack and Back-pack groups performed 12804 and 11935, respectively. Analyses revealed a main effect for Group, $F(2, 20) = 17.64$, $p < .001$ (ES = .64) and post hoc analyses confirmed that Experts performed significantly more training units than both Mid- and Back-pack triathletes, who did not differ.

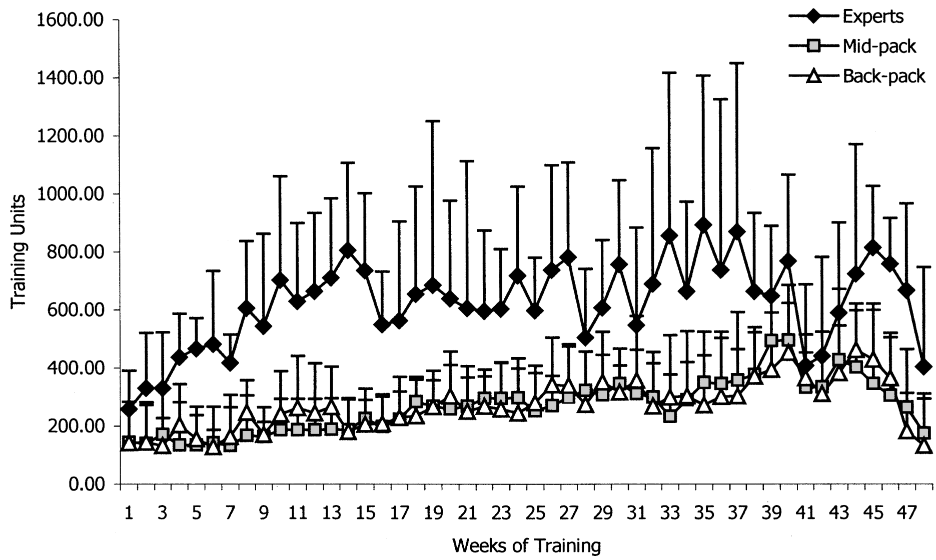

Figure 1. Training units for each week of training for Expert, Mid-pack, and Back-pack triathletes training year.

Mesocycles of Training

Figure 2 presents data from the Expert, Mid-pack and Back-pack groups for the 12 mesocycles (4-week blocks) of training. Consistent across groups was the build-up of training workload across the season; however, this build-up occurred more rapidly in Expert triathletes. Experts

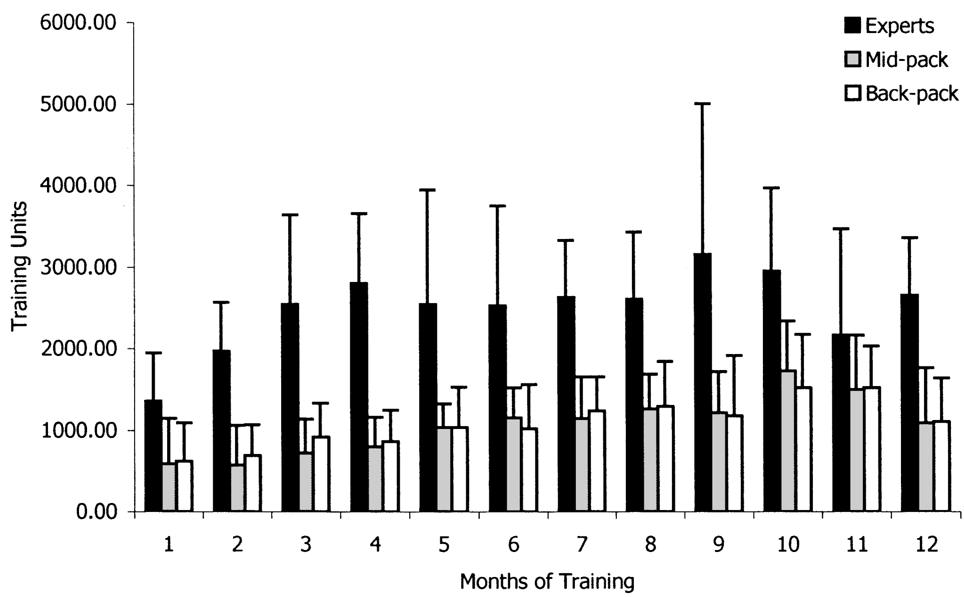

Figure 2. Training units for each mesocycle in the training year for Experts, Mid-pack, and Back-pack triathletes.

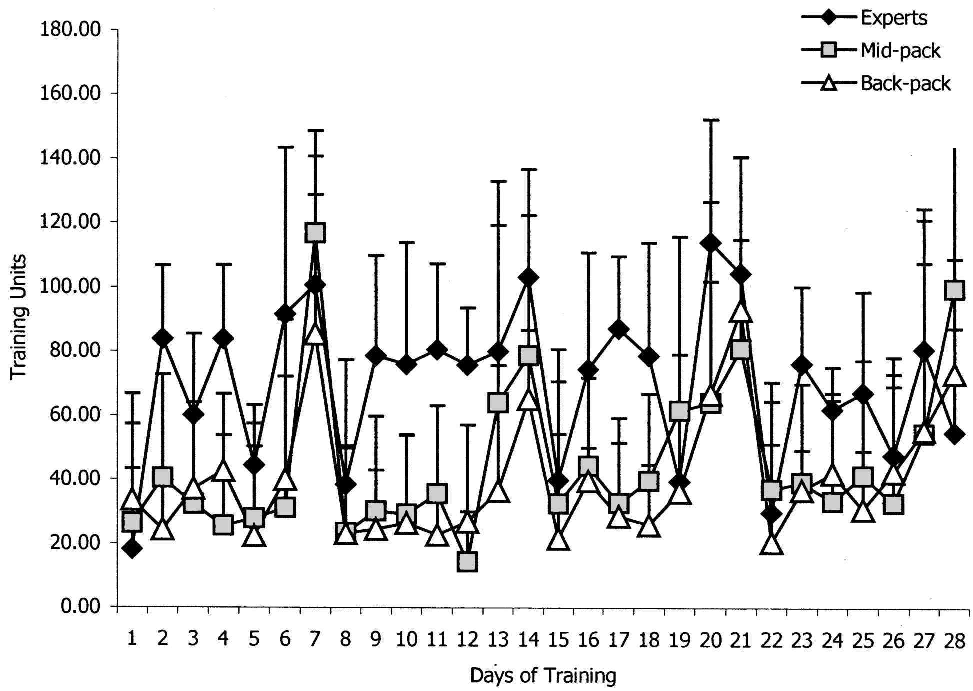

Figure 3. Training units per day for one mesocycle of training in Esxperts, Mid-pack, and Back-pack triathletes.

reached higher levels of output faster and as a result put in more training units per mesocycle for a longer period than the other two groups.

Microcycles of Training

Figure 3 displays the training units per day for four microcycles in the mesocycle occurring two months prior to the key race. The lines for the Mid-pack and Back-pack groups indicate training workload was lower during the week than during weekend training sessions (i.e., days 6–7, 13–14, 20–21, and 27–28). For the Experts, there was much less of a division between weekday training and weekend training. Results of the auto-correlation indicated that training in all three groups conformed to a 7-day cycle, showing strong serial dependencies at lags of 7, 14, and 21 days.

DISCUSSION

The Development of UE Triathlon Expertise

The need for specialized training during early stages of development, as advocated by the theory of deliberate practice (Ericsson et al., 1993), was not supported in this study. Typically, the UE triathletes were not involved in regular training in swimming, cycling, or running until at least mid-adolescence. The hours spent participating in other sports prior to beginning triathlon suggests a considerable depth of sport experience with the Expert and Mid-pack groups performing around 5,500 hours of other sport participation and the Back-pack group accumulating nearly 3,500 hours in other sports. While these findings support a diversified involvement in sport during early involvement, they also indicate that participation in other sports does not distinguish Expert from non-expert UE triathletes. Participation in a range of sports that are aerobic in nature (e.g., basketball, soccer) may provide the physiological stimuli required for gross adaptations that could be easily transferred to UE triathlon. The transfer of gross or general elements of performance during early stages of development has also been noted in team sports (Baker et al., 2003).

Progression from sport beginner to UE triathlete was similar across all groups. Of the core triathlon sports, the greatest amount of time was spent in running prior to beginning involvement in triathlon. This finding supports research indicating that UE triathletes typically come from running backgrounds (Zinkgraf, Jones, Warren, & Krebs, 1986). Running was followed by swimming, cycling, and then short-course triathlon participation. After spending at least two years competing in short-course events, athletes began UE triathlon competition. Although this progression indicates that participation in UE triathlon events is atypical, there were some similarities to the developmental progression outlined in other sports. As in other sports examined using the Stages of Sport Participation model (Côté, 1999; Côté et al., 2003), UE triathletes had an extended period of sampling prior to focusing on UE triathlon. However, this period was longer in duration than for other sports examined (e.g., Baker et al., 2003). Interestingly, the specializing stage, as demarcated by the decrease in activity involvement to two or three sports, was not evident in these results. Perhaps this was not surprising given that triathletes perform at least three training activities regularly. Specializing clearly means something different in UE triathlon than in single sports and therefore, the normal definitions are not applicable. According to Côté and colleagues (Côté et al., 2003; Côté & Hay, 2002) the specializing phase is typically a transition phase from the playful enjoyment of the sampling phase to the structured commitment of the investment phase. Using these criteria, the stage of involvement where athletes increase their training in one or all of the triathlon sports may be seen as the transitional phase before 'investing' in triathlon.

Results also indicated a significant degree of variation within the groups with respect to accumulated hours of training in swimming, cycling, running, and other sports, particularly prior to becoming a triathlete. This was somewhat expected given the various pathways athletes could take in their progression to UE triathlon (e.g., a strong background in running with little or no exposure to swimming or vice versa). Between-group differences in total hours spent in training resulted from both an earlier start age and a higher volume of training among the expert UE triathletes. Further, the Experts exhibited an incremental increase in training load from year to year (primarily in swimming and cycling) while Mid-pack and Back-pack triathletes remained constant or even decreased their involvement. The systematic increase in training load may be important in perpetuating continual adaptations to training stress. Consistent with the theory of deliberate practice (Ericsson et al., 1993), hours spent in sport-specific training clearly distinguished Experts from their lesser skilled counterparts. However, there was no evidence supporting the monotonic relationship between training hours and performance. In fact, results from this work support a power function as the best fit descriptor for the relationship between practice and performance (Newell & Rosenbloom, 1981). For instance, mid-pack and back-pack athletes were separated by 2,000 hours while mid-pack athletes and experts were separated by 6,000 hours. Since the differences in performance across the groups were similar (i.e., $\sim$ 2.5 hours of overall finishing time), these results signify that performance improvements become more arduous as one progresses in skill level.

Perhaps the most interesting result is that training time accumulated prior to investment at age 20 is not as significant to expertise in the UE triathlon as it is in other sports with earlier ages of peak performance. Experts were not distinguishable from their non-expert counterparts until after approximately 20 years of age (i.e., after they have begun triathlon training). This suggests that while the deliberate practice framework is quite capable of differentiating Expert UE triathletes from non-experts UE triathletes based on total hours of training, it is not capable of distinguishing them during early stages of development. Data from this study indicated that even experts were not becoming involved in UE triathlon until around 25 years of age. This is significantly later than the ages reported for athletes examined in previous studies, especially figure skaters (Starkes et al., 1996) and gymnasts (Beamer, 2001) whose careers would have ended before the age at which the UE triathletes' careers began. The later start for beginning training places less emphasis on deliberate practice during early stages of biological and psychological development.

Despite the later start in training, Expert UE triathletes performed volumes of training that were similar to or greater than Experts in other sports (e.g., Baker et al., 2003). From a skill acquisition perspective, the relative importance of early specialization and early diversification must be considered relative to the sport under examination and its age of peak performance. Sports that have later ages of peak performance will have more flexibility regarding the type and intensity of activities performed during early stages of development.

Managing Training Effort

Analyses of the training structure of the expert and non-expert groups supported both the theory of deliberate practice presented by Ericsson et al. (1993) and the theory of periodization postulated by Fry et al. (1992). Not only did Experts perform significantly more training than non-experts but their short and long-term approaches to training were more systematic in design and structure. These differences in training structure may influence the Expert's ability to perform greater amounts of training. Recuperation periods are essential for maximal physiological adaptation and the prevention of stress-induced injury (Bompa, 1983; Fry et al., 1991; Kenttä & Hassmén, 1998) as well as for avoiding staleness, overtraining, and burnout (Gould & Dieffenbach, 2002). By allowing adequate time for their bodies to regenerate and become accustomed to increased training loads, Experts are able to continue training at high workloads and thereby promote greater performance adaptations.

Conversely, the approach used by the Mid-pack and Back-pack UE triathletes was linear, indicating that they continually increased training load throughout the year without the periods of decreased training load shown in the Experts' training profile. This method of increasing training load is not as effective as the periodization approach (Bompa, 1983) and may be a factor explaining why the non-expert groups did not perform as much training as the Experts. Specifically, the linear plan may not have allowed for the recuperation necessary for maximal adaptation to training stimuli, therefore, non-experts were not able to increase their training load to the same extent as the expert group. If they increase their training load to the same extent as the Experts they run the risk of incurring injuries due to an inadequate recovery from previous training stress.

While an inefficient approach to training structure may partially explain the lower amounts of training in the non-expert groups, it is likely non-experts' training was more constrained by factors such as full-time employment and other commitments. The dramatic increase in training on the weekend for the two non-expert groups supports the notion that non-experts focused on factors other than triathlon training during the week. Experts typically have more invested in their performance and make training a priority; as a consequence, they were able to focus on performing training that was optimally designed for maximal physiological adaptations. Furthermore, a more flexible schedule allows the Experts to better balance the stress of training with necessary periods of recovery thereby avoiding the effects of overtraining (Gould & Dieffenbach, 2002).

Another noteworthy finding is the lack of differences between the Mid-pack and Back-pack groups on the training output variables. While there were clear differences between the groups with regard to performance (~2.5 hours difference in finishing time) there were no significant differences between the groups in either the amount of training they performed or the way this training was structured. Further, results indicated no differences among the groups in their participation in sports other than swimming, cycling, and running. Therefore, factors other than training may be important for distinguishing between levels of performance. For instance, nutrition and energy intake (Kimber, Ross, Mason, & Speedy, 2002) as well as cognitive orientation (Masters & Ogles, 1998) during competition are important determinants of performance in aerobic sports such as the UE triathlon. In addition, recent research (Gayagay et al., 1998; Montgomery et al., 1998) has suggested the possible role that specific genes may play in predisposing individuals to endurance sport success. Future research is needed to identify the factors other than training/practice that lead to differences in performance in this sport.

GENERAL CONCLUSIONS AND IMPLICATIONS FOR COACHES AND ATHLETES

Results support several tenets of the theory of deliberate practice (Ericsson et al., 1993). For instance, time spent in sport-specific training was a key discriminator of experts and non-experts. However, the relationship between practice and performance was non-linear, contradicting a fundamental principle of the deliberate practice framework. Moreover, a basic premise of deliberate practice, the need for early specialization, was not supported. Additional research is needed to determine the importance of early specialization in the acquisition of sport skill, particularly in light of the negative consequences associated with this approach (Wiersma, 2000). Given the unique nature of the UE triathlon, more research is required to determine the generalizability of these results to other UE and endurance sports.

What is clear from the present study is that experts perform training that is greater in both quantity and quality. The experts' approach to training is more systematic and progressive than their non-expert counterparts with a more balanced approach to managing training effort as suggested by Ericsson et al. (1993). Coaches and athletes are advised to consider not only the quantity of training but also how training is structured (e.g., periodization) when designing training programs for UE triathletes at all levels. Attention to these issues may result in superior performance and decreased risk of overtraining. Future research should also continue to examine the balance between the training stress that is optimal for performance adaptations and the recovery necessary to prevent overtraining, staleness, and burnout. A comprehensive outline of this relationship would further our understanding of the factors underlying the acquisition of elite levels of performance.

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