Université d'Ottawa · University of Ottawa

Deliberate Practice and the Acquisition of Expert Performance in Canadian Middle Distance Running

by
Bradley William Young

THESIS

Submitted to the School of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Arts in Human Kinetics

School of Human Kinetics
University of Ottawa

0-612-36757-6

ABSTRACT

The present research, comprised of two affiliated studies, specifically tested the Ericsson, Krampe, and Tesch-Römer (1993) framework for the acquisition of expertise in Canadian middle distance running. The conceptual framework posited that performance level was a monotonic function of accumulated amounts of deliberate practice. Ericsson and colleagues initially defined deliberate practice as domain-specific training activities that were highly relevant to improving performance, highly effortful in nature, and not inherently enjoyable. Study 1 tested this definition according to the runners' own perceptions of training. Contrary to the original conception of deliberate practice, results indicated that the most relevant and the most effortful training activities were also perceived as inherently enjoyable. Findings indicated that the definition for deliberate practice was not transferable from music to sport, but, rather, a modified conception of deliberate practice was required for athletics. Study 2 retrospectively compared accumulated amounts of deliberate practice between national, provincial, and club level runners across the initial nine years of their careers. Results indicated that attained performance levels were governed by a monotonic relationship with accumulated practice variables according to an inverse power law. Trends demonstrated that the national level runners began to invest more time into practice after nine years. Early in their careers, accumulated practice proved to be the primary predictor of running performance and the amount of supervised practice with a coach differentiated between the elite and club level athletes.

ACKNOWLEDGEMENTS

Two years ago, I embarked on a Master's degree so that I could claim a very small corner of academia as my own. This small corner of academia and the people I have encountered within it have remarkably given me much more, more than could ever be captured in these pages.

Foremost, I would like to thank *Dr. John Salmela*, the finest pedagogue I have encountered. Amidst my fits of anxiety and frustration, his efforts to "listen, challenge, and support" my work effectively resulted in this thesis paper. Dr. Salmela displayed an infectious passion for learning, a quality that I will strive to embody in my future endeavours as an educator. I am extremely thankful for the support of my *mother*, *father*, and *sister*, my three greatest fans, who have been cheering from the crack of the pistol to the break of the tape. I am grateful for the contributions of my academic colleagues in the "brainstorm crew", *Natalie Durand-Bush*, *Luiz Carlos Moraes*, *Gary Watanabe*, and *James Kallio*, who, week in and out, arrived with smiles, fresh insight, and constructive feedback. Furthermore, the finished product would not have been possible without the refinements suggested by my committee members, *Dr. Diane St.Marie* and *Dr. Pierre Trudel*. Partial funding provided by the Social Sciences and Humanities Research Council of Canada (410-94-0402) facilitated the collection of research data. Finally, I would like to salute *all the runners and coaches*, particularly the McGill clan, whose shared interest in this project gave me the impetus to push on. I apologise if I deceived you into believing I would arrive at the recipe for running expertise. It is very elusive. Keep running faster.

TABLE OF CONTENTS

INTRODUCTION

People have always marvelled at exceptional individuals whose performance in a domain is far superior to the rest of the population. Speculation as to the cause of these individuals' extraordinary abilities has indicted a range of possible explanations, some colored by almost folklorish qualities, still others were postulated by the empirical process. Emergent from empirical inquiries into the causes of expert performance has been a relatively unrefined dichotomy of accounts of expertise bearing resemblance to the nature versus nurture debate. On one hand, proponents of a "natural talent" perspective have argued that stable, genetic features are primarily responsible for expert performance (Galton, 1979; Malina, 1986). Alternatively, the developmental perspective claims that expertise is foremost a product of skill acquisition through extended practice (Ericsson, 1996; Ericsson, Krampe, & Tesch-Römer, 1993; Howe, 1990).

The Natural Talent Perspective: A Review and Critical Analysis

The popular talent account of expert performance is that extraordinary human accomplishments largely depend upon individuals inheriting certain gifts or biological traits. The implication is that only a person who has been blessed with receiving a special gift, for example, for middle distance running, will be capable of achieving outstanding performances within that domain (Galton, 1979; Malina, 1986; Howe, 1990). Sir Francis Galton (1979) originally expressed the belief in 1869 that an "assignable limit" is placed upon the potential achievement level for those people not lucky enough to receive the gift of talent. According to this logic, inter-individual differences in performance can be attributed to the relative amount of natural talent with which an individual has been endowed.

In sport, it is unsurprisingly common for spectators, commentators, and sport scientists to claim that natural talent is the primary mediator of exceptional performance. Extant scientific research has explored related issues: sport performance mainly as the product of genetic variance (Malina & Bouchard, 1986); the issue of heredity in endurance performance (Bouchard & Lortie, 1984); as well as the general topic of heredity and Olympic athletes (Bouchard & Malina, 1984). The prevalence of the natural talent perspective makes it necessary to briefly address and expose several concerns which were the impetus for this research. In running, for example, the idea that stable, genetic gifts are primarily responsible for elite performance is quite prominent (Anderson, 1995; Prokop, 1975).

There are two beliefs commonly affiliated with this perspective: that natural talent negates the need for maximal amounts of training; and that natural talents can easily and rapidly achieve an exceptional level of performance once they have acquired rudimentary running skills. Sustained practice is perceived as a compensatory device solely reserved for those lacking talent. Natural talent is a stable feature that remains remarkably unmodified by practice. Natural talent presumably reveals itself through an athlete's performances early in their career, thus making it an underlying principle of talent identification systems (Klavora, Georgevski, Forsyth, Higgins, Divaston, & Little, 1998; Petiot, Salmela, & Hoshizaki, 1987; Régnier, Salmela, & Russell, 1993; Russell, 1989; Salmela & Régnier, 1983).

The argument for natural talent as the primary determinant of elite running performance has recently been raised to explain the success of African distance runners. Track fans have attributed their dominance primarily to genetic endowment rather than to environmental factors and diligence in training (Anderson, 1995; Prokop, 1975). However, this same thinking has now permeated all calibres of competition, such that expert versus novice comparisons at the national or provincial levels are analogous to contrasts between Africans and non-Africans. In running, as in other sports, natural talent has effectively become a panacea for explaining the superiority of certain groups of athletes.

Traditionally, max VO_2 and the distribution of muscle fibre type have been cited as the key determinants of natural running talent (Fox & Matthews, 1981; Liquori & Parker, 1980; Noakes, 1991). The consensus appeared to be that, at least for physiological components of peak performance, there were stable physiological differences between the normal variation and the expert few (Fox & Matthews, 1981). It is clear that a genetic predisposition for physical stature is advantageous for sports such as gymnastics and basketball. Undoubtedly, a moderate heretibility factor exists for middle distance running - minimum values for the appropriate physiological "plumbing" are required to gain membership into competitive circles. However, there are a number of empirical findings that present the natural talent perspective in a less convincing light.

First, physiological features that have typically been considered stable markers of running performance have demonstrated remarkable adaptation and plasticity in response to training. Aerobic power and capacity (Boulay, Lortie, Simoneau, & Bouchard, 1986; Elovaino & Sundberg, 1983), aerobic alactic capacity (Malina & Bouchard, 1986), muscle fibre distribution

(Andersen & Henriksson, 1977; Howald, 1982; Jansson, Sjodin, & Tesch, 1977; Jolesz & Sreter, 1981; Monster, Chan, & O'Connor, 1978; Schantz, Billeter, Henriksson, & Jansson, 1982; Tesch & Karlsson, 1985), and muscle oxidative enzyme activity (Howald, 1976; Komi, Viitasalo, Havu, Thorstensson, Sjodin, & Karlsson, 1977; Malina, 1986), have all proven to be modifiable by real or simulated training. Howald (1982) went so far as to suggest that the inadequate length and intensity of training stimuli in such studies were responsible for previous researchers' failure to demonstrate the adaptable nature of the physiological system.

In fact, the modifiability of physiological markers occurs in response to highly domain-specific training over extended periods of time. An interesting study by Tesch and Karlsson (1985) demonstrated that physiological adaptations, e.g., high max VO_2 or an appropriate combination of muscle fibre types, were not representative of a generalized athletic orientation, but rather were acquired via highly intensive and relevant training. Tesch and Karlsson examined the muscle fibre compositions of elite middle- and long-distance runners, and kayakers who had engaged in a minimum of four years of sport-specific training. For all participants, tissue samples were obtained for muscles in the leg and the back. The researchers found that the runners had a significantly higher percentage of slow-twitch fibres in the leg muscles than all other groups, but the runners' back muscles were no different from those of the control subjects. The situation was reversed for the kayakers: the paddlers had a substantially higher percentage of slow-twitch fibres in the back muscle than all other groups, but they were no different from the control group in terms of leg muscle fibre composition. From these and other findings, Tesch and Karlsson argued that differences in the muscles of elite athletes occur only for muscles specifically trained for a sport, with no differences for untrained muscles. Their findings supported the notion of domain-specificity for physiological adaptations.

Second, physiological features that have long been considered markers for exceptional performance have not been shown to be robust discriminating variables at elite levels of competition (Noakes, 1991). At the international level, distance runners who possessed what would be considered lower physiological values, were frequently able to surpass their genetically "superior" counterparts. Furthermore, distance runners demonstrating similar physiological profiles showed substantial variability in actual performance. These findings suggest that features such as max VO_2 and muscle fibre distribution are less discriminating markers of elite performance and that non-genetic factors may play a more important role than previously suspected.

From an empirical point of view, in order to convince skeptics that inborn features are the primary cause of exceptional performance, geneticists must be able to isolate the most salient genes for middle distance track (Anderson, 1995; Howe 1990; Manners, 1975). Scientists must also show that these genes are found to be more prevalent in the most elite runners. Neither of these two tasks has been accomplished to date. Until the middle distance gene is discovered, genetic differences can only be studied indirectly by examining physiological discrepancies between cross-sections of different populations or between different skill groups. A Swedish research team (Saltin, Larsen, Terrados, Bangsbo, Bak, Kim, Svedenhag, & Rolf, 1995) compared the expectedly talented Kenyan population against age-controlled Scandinavian and American samples. Findings indicated that sedentary Kenyan adolescents shared the same aerobic capacities as sedentary Danish teenagers. Saltin and colleagues also compared several cross-sections of Kenyan and American populations in regards to aerobic capacity. Included in the study were sedentary and active adolescents, serious high school runners, and senior elite runners. Results revealed that the progressions in aerobic capacity were exactly the same for both the Kenyans and the Americans. If the Kenyans were genetically superior, they would be expected to demonstrate markedly higher levels of max VO_2 than their Scandinavian or American peers. This was not the case.

In the case of the Kenyans, leading geneticists have admitted that there is "currently no evidence that they are genetically superior" (Anderson, 1995). Even amongst the Kenyans, no one tribal group has cornered the market on genetic super material (Anderson, 1995; Manners, 1975). Different tribes of non-interbreeding people have produced top runners - evidence that genetics is not the paramount factor even amongst the heralded Kenyan athletes. Similarly, there is no concrete evidence to suggest that performance differences between elite middle distance athletes can be primarily attributed to natural talent. This perspective appears to have come to prominence in a flood of fanfare and media fabrication, but also in the absence of scientific evidence. Based on available research, sports scientists have concluded that environmental factors such as long-term training and lifestyle are far more important in determining exceptional running performance than natural talent (Anderson, 1995; Prokop, 1975).

The preoccupation with natural talent has elicited a defeatist attitude expressed by many aspiring distance runners: "I work, I do the miles, the work is the same as the champions do, maybe even harder, but the results are less significant" (Montville, 1997, p.71). Incidentally, these same athletes will attribute their performance shortcomings to deficits in natural talent. A prominent running researcher has expressed concerns regarding the convenience of such attributions:

> It is enough to believe that exceptional athletes are born with a vast talent that places them head and shoulders above the pack. As a result, we don't need to concern ourselves too much with how they train. (Anderson, 1995, p.7)

In an attempt to reverse our focus toward the training characteristics of the most elite runners, this thesis will examine the process for the acquisition of expert performance in Canadian middle distance running. Central to this investigation will be the theoretical framework of deliberate practice for the acquisition of expertise.

The Deliberate Practice Framework for the Acquisition of Expertise

An alternative framework for the acquisition of exceptional performance must be able to trace the symbiotic relationship between practice and performance, and be able to account for the processes that shape aspiring performers to become the most elite in their field. Research with highly skilled performers in a number of domains has produced such a theoretical framework for the acquisition of expert performance (Ericsson, 1996; Ericsson et al., 1993; Krampe, 1994; Krampe & Ericsson, 1996). This framework is generalizable to numerous real-life skills and has previously been shown to be applicable to the arts (Ericsson et al., 1993; Krampe, 1994;

Partington, 1995; Sloboda, 1996), sciences (Patel, Kaufman, & Magder, 1996), games and sport (Charness, Krampe, & Mayr, 1996; Helsen, Starkes, & Hodges, 1998; Hodges & Starkes, 1996; Starkes, Deakin, Allard, Hodges, & Hayes, 1996). Based upon this framework, certain hypotheses about the developmental history and practice intensity of elite performers will be derived, and subsequently applied to middle distance running.

The claim underlying all research on the acquisition of expertise is that "practice makes expert." Simply stated, high-level performance is primarily the result of an extended process of development mediated by large amounts of appropriate and intensive training (Ericsson, 1996; Ericsson et al., 1993; Krampe & Ericsson, 1996). This extreme environmental position maintains that expertise is the extreme outcome of long-term, specific adaptation to overcoming the constraints within a domain. This theoretical framework discounts any determining role of natural talent in the acquisition of expertise: innate characteristics are recognised only so much as they influence immutable physical characteristics such as stature, or personality factors, like emotionality and general activity levels (Ericsson et al., 1993).

The most important constraint is the need for extensive training and preparation (Charness et al., 1996; Ericsson, 1990; Ericsson, 1996; Ericsson et al., 1993; Krampe, 1994; Starkes et al., 1996). A wealth of research supports the position that the achievement of expertise requires sustained and systematic preparation for a miminum of 10 years. The "10 year rule of necessary preparation" has been empirically supported in multiple domains: chess (Charness et al., 1996; Simon & Chase, 1973), mathematics (Gustin, 1985), music (Ericsson et al., 1993;

Krampe, 1994; Partington, 1995; Sosniak, 1985), medicine (Patel et al., 1996), and sport (Bloom, 1985; Helsen et al., 1998; Hodges & Starkes, 1996; Kalinowski, 1985; Monsaas, 1985), including running (Doherty, 1964; Wallingford, 1975). Studies have confirmed that, regardless of the starting age for training, a continuous 10 year period of preparation is necessarily linked to the acquisition of expertise (Ericsson et al., 1993).

Although the "10 year rule" is a necessary condition, it alone is not a sufficient condition for the acquisition of expertise. Simon and Chase (1973) postulated that 10,000 hours of goal-directed practice was necessary for the acquisition of expertise. This abundant amount of practice may very well be a prerequisite for the acquisition of exceptional performance, but on its own, simple practice is insufficient. Merely engaging in sufficient amounts of preparation does not lead to maximal performance. The microstructure of the practice, as well as means of overcoming resource, effort, and motivation constraints must be assured (Ericsson et al., 1993). Most importantly, the goal-directed nature of the domain-specific practice activities is believed to determine the rate of skill acquisition. This theoretical framework posits that participation in the most relevant forms of training is most effective for acquiring expertise.

Ericsson and colleagues (Ericsson, 1996; Ericsson et al., 1993; Krampe & Ericsson, 1996) coined the most relevant forms of training for improving performance within a domain as "deliberate practice" (DP). DP consists of goal-directed activities created for the sole purpose of attaining and improving skills. In this manner, DP can be distinguished from domain-related experiences and everyday activities in which skill development may be an indirect result. DP is highly effortful and demands high levels of concentration, thereby differentiating it from casual practice activities and spontaneous play. DP is not inherently enjoyable, nor inherently motivating, and, if engagement in DP is separated from its consequences, it is evident that there are no external awards for engaging in DP, as is the case for paid work. However, in sport, seminal research has suggested otherwise - that DP is relatively enjoyable (Hodges & Starkes, 1996; Helsen et al., 1998). DP is highly structured and often involves activities selected by a coach to facilitate skill acquisition (Salmela, 1996; Starkes et al., 1996). Selected elements of rote repetition are woven with innovative, engaging, or diverting activities which allow the individual to continually refine their performance using knowledge of results and feedback (Ericsson et al., 1993).

DP assumes a central role in the theoretical framework for the acquisition of expert performance (Ericsson et al., 1993). As previously mentioned, "practice makes expert" - expert performance is primarily the result of an extended process of acquisition mediated by large amounts of DP. At any point in a career, individual differences in performance are a function of acquired skills or acquired physiological characteristics, which in turn are directly related to accumulated amounts of DP. A "monotonic benefits assumption" dictates the direct relationship between amounts of accumulated DP and attained level of performance. Essentially, this monotonic relation predicts that differences in the accumulation of DP will reliably account for both inter-individual and expert-novice differences in performance (Figure 1). Furthermore, the monotonic relation dictates that differences in the accumulation of DP will reliably account for many of the physiological differences which distinguish between elite performers in sport (Ericsson, 1996; Ericsson et al., 1993; Helsen et al., 1998; Hodges & Starkes, 1996; Krampe & Ericsson, 1996). This predicted monotonic relationship has been shown to take the functional form of the power law of practice (Newell & Rosenbloom, 1981). Laboratory tasks examining the mechanisms of skill acquisition have indicated that accumulated DP leads to improvements in performance according to an inverse power law, such that each increment in performance requires an additional log unit of practice (Anderson, 1982; Ericsson et al., 1993; Newell & Rosenbloom, 1981).

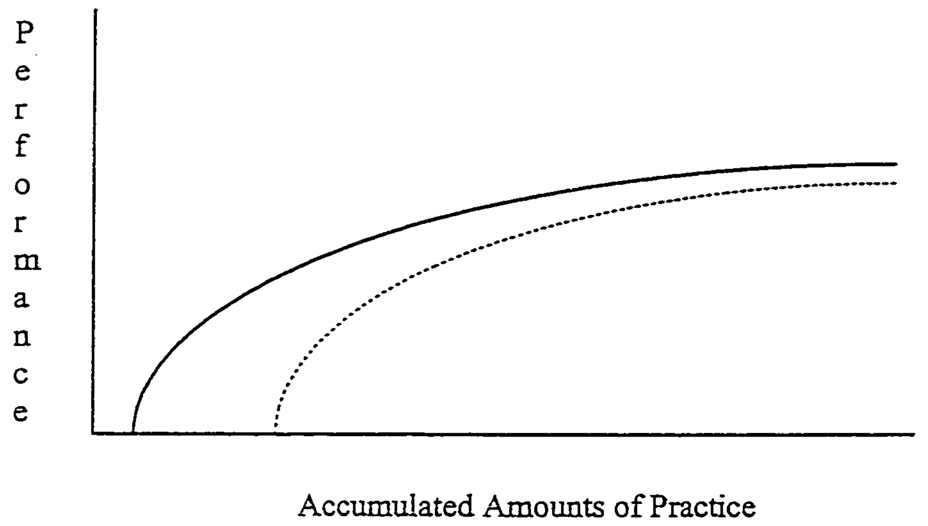

Figure 1. The predicted monotonic relation between accumulated amounts of practice and attained level of performance. The solid line shows the performance associated with an early starting age. The dashed line shows performance for a later starting age. Both early and late starters participate in practice of equal intensity. (adapted from Ericsson et al., 1993, p.387)

The monotonic benefits assumption proposed by the DP framework accounts adequately for one of the common observations made by natural talent proponents (Ericsson et al., 1993) (Figure 1). Runners who start systematic training at an early age will have a higher level of performance throughout their development (the solid line in Figure 1) than those who practice equally as hard but start at a later age (dashed line). When the late starters begin DP they will experience rapid improvements and will initially narrow the performance gap with the early starters. Frequently, these late starters will be deceived into believing that they will eventually attain the performance level of individuals with earlier starting ages (Ericsson et al., 1993). According to the monotonic relation between practice and attained level of performance, however, the rate of performance improvements eventually decreases and becomes less perceptible (Ericsson et al., 1993). In reality, the difference between the two groups will remain a function of the monotonic benefits rule; if motivational factors and training intensity are controlled for, then the late starters will never surpass the early starters.

> It is impossible for an individual with less accumulated practice at some age to catch up with the best individuals, who have started earlier and maintain maximal levels of DP not leading to exhaustion. (Ericsson et al., 1993, p.393)

The late starting runners, however, are quite likely to make an incorrect attribution - that the performance level of the earlier starting group is due to natural running talent rather than their previously accumulated practice (Ericsson et al., 1993).

Where there are no apparent differences in starting age for practice, the DP framework will generally attribute inter-individual, as well as group differences in performance level to discrepancies in accumulated practice over a considerable period of systematic training. Ericsson et al. (1993) originally tested this theoretical tenet in the domain of music by examining groups of violinists who had practiced the violin for longer than 10 years. The investigators contrasted measures between three performance groups: "best" violinists, "good" violinists, and "lower criteria" violinists. The performers were asked to retrospectively estimate weekly amounts of practice since they had started playing. These estimates, in turn, were converted to annual and cumulative career totals. For all three groups, retrospective estimates of time spent practicing alone with the violin since beginning playing were found to increase in a monotonic fashion. Results also indicated a remarkable correspondence between acquired performance level and accumulated amounts of practice alone with the violin. By the age of 18, the best group had engaged in significantly more practice alone with the violin than the good violinists. The best violinists had practiced more during the earlier years, especially around the age of puberty, or 15 years, in comparison to the good group. Both the best and the good groups had significantly higher totals than the lower criteria violinists. Since all three groups were shown to begin practice at similar ages, the differences in total accumulated amounts of practice were, thus, attributed to differential amounts of DP.

These results were replicated in a second study with pianists (Ericsson et al., 1993; Krampe, 1994). Investigators derived weekly amounts of practice from the performers' biographical estimates and then calculated cumulative totals of practice for each year of life. Results indicated that expert pianists practiced significantly more than amateurs for each year of life except at the age of five years. In comparisons of the accumulated practice as a function of age, the expert pianists had engaged in substantially more cumulative amounts of practice than their amateur counterparts by the age of 18.

A third investigation known as the Leverhulme Project (Sloboda, 1996) studied the practice-performance relationship in young instrumental musicians. Musicians were asked to estimate daily measures of formal practice for each year of their life. This allowed researchers to calculate the average number of hours of formal practice performers required to reach each progressive grade of musical performance. The relationship between practice and achievement level was strongly confirmed. Moreover, the practice-performance relationship did not break down even at low levels of achievement. Investigators concluded that accomplished young instrumentalists gained success earlier than low achievers due to their quicker accumulation of requisite amounts of practice.

Next, Charness et al. (1996) investigated the life-span acquisition of performance in chess. Highly-skilled Grandmasters and moderately-skilled players were asked to report weekly averages of practice for each year of their life. This data was then extrapolated to create estimates of accumulated practice across the players' careers. Using a continuous scale of performance, researchers correlated the chess players' performance ratings with accumulated amounts of practice. Results indicated that practice alone, which arguably most resembled DP for chess, was highly correlated with chess performance and that log cumulative hours of practice alone was a significant predictor of current chess rating. Based on log cumulative hours of practice alone, the researchers plotted the number of hours it would be expected to take a young player to become a Grandmaster. This predicted the relationship between accumulated practice and ultimate performance level fit the monotonic functional form postulated in the theoretical framework.

The initial investigation in sport specifically tested the DP framework with wrestlers (Hodges & Starkes, 1996). The wrestlers had all begun the sport at similar ages and had practiced for a requisite 10 years. The researchers compared measures between "international" level and "club" level wrestlers. Wrestlers retrospectively recalled weekly amounts of practice at the start of their career and for every three years onward. Weekly estimates were converted to annual and cumulative career totals. Results showed that international wrestlers devoted more time to practice than their club level counterparts as early as three years into their careers, with this trend becoming more pronounced further into their respective careers. Results revealed no significant difference between the performance groups for cumulative amounts of wrestling practice alone, however, there was a significant difference between the performance groups for cumulative amounts of practice with others. Arguably, practice with others was a better representation of DP in wrestling than practice alone. Perhaps this could be attributed to the presence of a coach and other athletes capable of providing feedback and adequate strategies for skill acquisition.

Most recently, Helsen et al. (1998) investigated the concept of DP in the team sports of field hockey and soccer. Athletes from both sports were asked to retrospectively recall amounts of weekly practice at different intervals across their careers. Like the studies before, weekly amounts were translated into accumulated amounts across their careers. Results indicated that the

"10 year rule of preparation" was a valid construct: beyond nine years of systematic training, international-level players began to commit a greater investment into training compared to national and provincial groups. The monotonic relationship between accumulated amounts of DP and attained level of performance was once again demonstrated. For both the hockey and soccer samples, the international group had accumulated more DP across their career than the national and provincial groups; the national group had accumulated more DP across their career than the provincial group.

Although no running studies have examined the concept of DP, many have documented the relationship between practice and attained level of running performance. Hagan, Smith, and Gettman (1981) found that, among high-level adult runners, the amount and intensity of practice emerged as the best predictor of running performance. Even for an extremely short period of observation, the nine weeks preceding a marathon race, Hagan and colleagues found that the length of training runs and the total weekly training mileage accounted for nearly half of the variance in actual running times in the marathon. Another longitudinal study examined the training practices of late adolescent runners at different performance levels (Sack, 1980). Apart from the number of appearances at national championships, the most adequate predictor of best running performance was the frequency of training. Runners who had improved their performances over the course of the study reported more training alone. A review of training prescriptions revealed that championship competitors devoted significantly more time to practice and covered longer running distances than their advanced and novice counterparts (Glover &

Schuder, 1988). In particular, the highest skilled runners spent proportionally more time on a select few activities - interval training and fartlek (speed play) to improve endurance and speed (Glover & Schuder, 1988; Noakes, 1991). Although the observed developmental periods were extremely short and DP was not defined per se in the aforementioned studies, the findings were suggestive of a main effect of performance level on amount of practice. They were, therefore, precursors to a study on the role of DP in running in which the monotonic benefits assumption was empirically tested.

If accumulated practice can be singularly linked to performance improvements and, ultimately the acquisition of expert performance, it only makes sense for an individual to want to maximise their amounts of DP (Ericsson et al., 1993). There are two possible ways of increasing accumulated DP: by beginning systematic practice at a younger age; or by increasing the weekly amount of DP (Ericsson et al., 1993). The latter approach is neither short-lived, nor simple. The maximising of DP is a lengthy process governed by environmental constraints regarding resources, motivation, and effort (Ericsson, 1996; Ericsson et al., 1993). In middle distance running, DP requires numerous resources - available time and energy for the individual, access to track facilities, knowledgeable coaches, adequate training partners, and proper equipment. Since DP is not inherently enjoyable, the athlete must be consistently motivated to participate in the appropriate activities. Indeed, it has been reported that long-distance runners with markedly improved performances rated higher on motivation scales (Sack, 1975). Finally, DP is such a mentally and physically taxing activity that these efforts can only be sustained for a limited time each session. Consequentially, the microstructure of training must respect a balance between maximal bouts of effort and opportunities for recovery in order to avoid athlete burn-out. A final consideration for the maximising of DP is that the microstructure of training is evolutionary in nature. Typically, as athletes increase their amounts of practice, they also adapt their relative training emphases to reflect their current performance level and the relevant activities needed to further improve performance beyond that level (Ericsson et al., 1993; Ericsson, 1996). In track, for example, an athlete who has trained for several years to consolidate their aerobic and upper-end anaerobic conditioning may then emphasise significantly more speed play in order to reach higher levels of performance.

Evidently, there was support for the concept of DP and the acquisition of expertise in music and sport. There were, however, various stipulations that warranted an empirical study on DP for middle distance running. Hodges and Starkes (1996) noted that environmental differences between music and sport could potentially have some bearing on the validity of the DP framework for the acquisition of expertise in sport. Further research was required to test the validity of the DP framework in the athletic domain. Ericsson and colleagues (1993) suggested that track was a best-case scenario for empirically measuring the development of expert performance. For several reasons, track was probably the most suited of all the possible sports for monitoring the development of expert performance. Unlike previously studied domains, track had undisputed, objective, univariate measures of performance that did not require an extrinsic validation of expertise. The fact that runners are renowned for keeping highly detailed training logs facilitated the collection of accurate, retrospective data. In previous research, participants' retrospective recall from memory was inclined to overestimate amounts of practice (Ericsson et al., 1993; Helsen et al., 1998; Hodges et al., 1996; Krampe, 1994). Since the retrospective data in this investigation was derived predominantly from the training logs of athletes, the data represented a more accurate account of practice.

There were many additional implications for this particular empirical study in middle distance running. Extant research on running suggested a main effect of performance level on practice (Glover & Schuder, 1988; Hagan et al., 1981; Noakes, 1991; Sack, 1980). The aforementioned studies all preceded the conceptualisation of DP: researchers used "practice" or "involvement" to loosely define all training-related activities, whereas the present study distinguished DP from other training activities. Furthermore, the present study was directed specifically by the proposed monotonic benefits relationship between practice and performance. Previous findings were derived from observed developmental periods shorter than a four year duration (Glover & Schuder, 1988; Hagan et al., 1981; Noakes, 1991; Sack, 1980). The present research traced the entire developmental process of an athlete from the initiation of systematic practice to approximately 10 years into their career. In sum, the present research was expected to not only rectify empirical oversights on the part of previous studies, but more importantly, to frame any significant findings within the DP conceptualisation of expertise acquisition. Ultimately, the purpose of this study was to specifically test the DP framework for the acquisition of expert performance in the sport of middle distance running.

Review of Methodology

All of the aforementioned studies (Ericsson et al., 1993; Helsen et al., 1998; Hodges et al., 1996; Krampe, 1994) implemented two methodologies to explore the DP framework in their respective domain: 1) activity rating scales; and 2) retrospective recall from memory. The ratings scales effectively measured performers' perceptions of domain-related practice activities. The participants were asked to rate a taxonomy of training activities in order to determine which activities qualified as DP. The present research implemented similar rating scales in order to define DP a priori to the retrospective analyses (Appendix C).

The retrospective recall methodology in the aforementioned studies (Ericsson et al., 1993; Helsen et al., 1998; Hodges et al., 1996; Krampe, 1994) was used to reconstruct performers' accumulation of practice across a career. Findings supported the reliability of this recall approach even after a long interval of retention: in each study, the most recent retrospective estimates were highly correlated with amounts obtained from recent diary procedures (Ericsson et al., 1993; Helsen et al., 1998; Hodges et al., 1996; Krampe, 1994). However, there was a tendency for participants to overestimate their retrospective practice - to record the amount of practice they had aspired to do, rather than the amount they had actually done (Ericsson et al., 1993). The present research adopted a similar retrospective recall methodology, but it was based on participants' recall from training logs rather than from memory (Appendix C). It presumably represented a more precise tool for recall and one that did not require validation via a diary procedure.

An Outline of the Studies

The purpose of this research was to specifically test the DP framework for the acquisition of expert performance in the sport of middle distance running. To accomplish this, the investigation adopted a two-part research strategy. In Article 1, domain-specific DP activities were defined according to athletes' perceptions of training. In Article 2, the monotonic relationship between accumulated practice and attained level of performance was tested across three skill level groups. More importantly, the different performance level groups were contrasted for accumulated measures of DP. Analyses also traced the relationship between accumulated practice and attained level of performance across a career. Finally, regression analyses identified key variables in a predictive matrix for performance in middle distance running.

A number of hypotheses were postulated based on previous work and the theoretical tenets of the DP framework. In Article 1, it was expected that runners would perceive DP as consisting of activities that were highly relevant to improving performance, that demanded high levels of effort and concentration, and that were not inherently enjoyable to participate in. It was expected that runners from three different performance levels would perceive similar sets of activities as DP. In Article 2, it was expected that the monotonic relationship between accumulated amounts of practice and attained level of performance would be demonstrated, as well as the expected inverse power law of practice that it obeyed. Finally, it was hypothesised that results from hierarchical regressions would indicate that accumulated DP was the most significant predictor of middle distance running performance.

ARTICLE 1

Deliberate Practice According to Middle Distance Runners' Perceptions of Training

Abstract

The Ericsson, Krampe, and Tesch-Römer (1993) framework for the acquisition of expertise described deliberate practice as training most relevant for improvement of performance within any domain. Ericsson et al. (1993) concluded from research with musicians that deliberate practice is highly effortful, but not inherently enjoyable. The object of this study was to specifically test the definition of deliberate practice with Canadian middle distance runners. Eighty-one runners rated a list of track practice activities and track-related activities according to each activity's relevance for improving performance, the amount of effort and concentration required to perform each activity, and how enjoyable they considered their participation in each activity. Contrary to the original conception of deliberate practice (Ericsson et al., 1993), results indicated that the most relevant and the most effortful activities were also perceived as most enjoyable. Runners perceived concentration as distinct from the physical effort in their training. No significant differences were found between national, provincial, and club performance groups in terms of the athletes' perceptions of track practice and track-related activities. Finally, a set of deliberate practice activities for middle distance track was identified according to a modified conception of deliberate practice for sport.

Key Words: Deliberate practice, Expertise, Running.

Ericsson, Krampe and Tesch-Römer (1993) introduced a framework for the acquisition of expertise based on the premise that practice is the foremost mediator of exceptional performance. Their theoretical framework discounts any determining role for innate characteristics, rather, it posits that exceptional levels of performance are governed by, and ultimately the result of participation in deliberate practice (DP). DP is described as highly structured, goal-directed practice deemed most relevant for improving performance in a domain (Ericsson, 1996; Ericsson et al., 1993). By definition, DP consists of activities in which participation is highly effortful, but not inherently enjoyable.

DP is distinguishable from other domain-related experiences and everyday activities in which skill development may be an indirect result (Ericsson, 1996; Ericsson et al., 1993; Krampe & Ericsson, 1996). DP is highly structured, by which elements of rote repetition are selected and woven with innovative, engaging, or diverting activities that allow the individual to continually refine their performance using knowledge of results and feedback. DP demands comparatively more physical effort and concentration than casual practice or spontaneous play, such that training bouts are delicately balanced with recovery in order to optimize skill acquisition. As a consequence of the effortful constraints, individuals engaging in DP must sustain high levels of motivation. Finally, if participation in DP is separated from its consequences, there are no external rewards for engaging in DP, as is the case for paid work.

Ericsson et al.'s (1993) central thesis is that expert performance is primarily the result of an extended process of acquisition mediated by large amounts of DP. Differences in the accumulation of DP have been shown to account for inter-individual differences in skill acquisition as well as for many physiological characteristics distinguishing elite performers (Ericsson, 1996; Ericsson, 1997; Ericsson et al., 1993; Hodges & Starkes, 1996; Krampe & Ericsson, 1996). Thus, the definition of DP underlies all the empirical studies that have examined the acquisition of exceptional performance, as well as novice-expert and interindividual performances differences within a domain.

Ericsson et al. (1993) initially tested their definition of DP in the domain of music. The investigators contrasted measures between three performance groups of violinists, all of whom had played their instruments for longer than 10 years. Violinists were asked to rate a composite list of their own practice and everyday activities according to three dimensions - relevance to improving performance, inherent enjoyment of the activity, and effort required to perform the activity. Results failed to yield any differences between the three performance groups in terms of their perceptions of practice. The violinists rated practice alone with the violin, taking violin lessons, and engaging in solo performances as the three most relevant activities. The same three activities were perceived as highly effortful in nature. However, it is the current authors' interpretation of Ericsson et al.'s (1993) results that their three most relevant and effortful activities were also judged as relatively enjoyable compared to the majority of the practice and everyday activities. Furthermore, the six most relevant practice activities were rated more pleasurably than the majority of the practice and everyday activities. Sleep was found to be a remarkably relevant and enjoyable everyday activity, notably for its role in recovering from the effort constraints of training.

When Ericsson and colleagues (1993) first conceptualized DP, its definition as highly relevant, effortful, but not inherently enjoyable practice, was believed to be generalizable across domains. Recently, two studies have tested whether the definition of DP for music can be reliably imported to the domain of sport (Helsen, Starkes, & Hodges, 1998; Hodges & Starkes, 1996). Hodges and Starkes (1996) tested the definition of DP in the sport of wrestling. International- and club-level wrestlers who had been practicing for a requisite 10 years evaluated a repertoire of sport-related and everyday activities according to the dimensions of relevance, enjoyment, and effort, plus a fourth scale for concentration to differentiate between physical and mental effort. Several important findings emerged: first, activities judged to be the most relevant were also perceived as relatively more enjoyable than the majority of practice activities; second, concentration appeared to be a separate factor from effort; third, the dimension of concentration correlated most highly with relevance; and, fourth, both the international- and club-wrestlers shared the same perception of practice activities according to the four dimensions. Wrestlers' ratings ultimately identified mat work, e.g., sparring, as the most relevant activity for improving performance. As was the case for music (Ericsson et al., 1993), sleep was perceived as a highly relevant and enjoyable activity for improving wrestling performance.

Helsen et al. (1998) similarly examined the sport-specific definition of DP in the team sports of field hockey and soccer. They found that, in both individual and team practice settings, the practice activities that were judged most relevant were also perceived to be most enjoyable.

In accordance with the model of sport commitment (Carpenter, Scanlan, Simons, & Lobel, 1993; Scanlan, Carpenter, Schmidt, Simons, & Keeler, 1993a, 1993b), the investigators posited that sport enjoyment, including enjoyment during practice, was a salient factor explaining athletes' long-term commitment to their domain. In terms of the dimension of concentration, results confirmed that it was most highly correlated with relevance. Furthermore, the athletes' perceptions clearly differentiated concentration from the dimension of effort. Again, researchers found no differences between international-, national-, and provincial-calibre players for perceptions of practice according to the dimensions of relevance, effort, concentration, and enjoyment. Soccer players' perceptions revealed specific ball games and tactics, technical exercises, and running as the most relevant forms of training. Likewise, field hockey players rated games and tactics, practicing technical skills, running, and game-analysis exercises as activities most instrumental for improving their performance. Players from both sports also perceived sleep as a highly relevant everyday activity.

Research endeavors (Helsen et al., 1998; Hodges & Starkes, 1996) in the domain of sport have both reaffirmed and challenged the original definition of DP (Ericsson et al., 1993). Findings have indicated that DP is still regarded by athletes as the most relevant and effortful training activities in their domain, yet sporting participants have seemingly supported the validity of an additional dimension for concentration. A more contentious issue is the dimension of enjoyment and whether DP is not inherently enjoyable. The perceptions of wrestlers, soccer, and field hockey players have suggested otherwise, that highly relevant and effortful practice is relatively enjoyable. Finally, research in both sport and music has agreed that performers of varying skill levels share similar perceptions of practice.

The purpose of this study was to specifically test Ericsson et al.'s (1993) definition for DP in a sport-specific situation. If DP is domain-specific, researchers have questioned the relevance of the definition to a general framework for the acquisition of expertise (Helsen et al., 1998). The present study intended to determine whether the definition of DP could be transferred across domains, i.e., from music to sport, or whether domain-specific concessions would be necessary for its application in sport. Middle distance runners' current perceptions of track practice, track-related, and everyday activities were evaluated according to dimensions of relevance, effort, concentration, and enjoyment. The primary objective was to identify activities constituting DP as well as activities that facilitate recovery from practice. A second purpose was to assess whether certain training activities would discriminate between performance levels. Simply stated, did elite athletes perceive specific activities in a different manner than their lesser counterparts?

Method

Participants. Eighty-one Canadian middle distance track athletes participated in the study. Each participant voluntarily participated in the research following the administration of a letter of information and informed consent (Appendix B). Each participant was currently training for and competing in either the 800, 1500, or 3000 m events. The athletes were assigned to one of three performance groups based on their personal record of performance over the past 12 months using the Athletics Canada Olympic Trials (1996) performance standards. The 3000 m performance criteria were extrapolations of the 800 and 1500 m standards using the Mercier Scoring Tables, a tool for normalizing track results across different events (Mercier & Beauregard, 1994). The *National* group (*Nat*) was comprised of 31 athletes (19 males and 12 females) who had run faster than the 1996 Olympic Trials Provisional Qualifying Standard (Male: 800 m = 1:52.50; 1500 m = 3:48.00; 3000 m = 8:12.40; Female: 800 m = 2:09.00; 1500 m = 4:28.00; 3000 m = 9:35.10). More specifically, it consisted of 12, 15, and 4 athletes from the 800, 1500, and 3000 m events, respectively. The *Provincial* (*Prov*) group was comprised of 34 athletes (31 males and 3 females) who had not achieved the Olympic Trials qualifying standard, but who had achieved a performance time that was within 5% of the aforementioned criteria (Male: 800 m = 1:58.12; 1500 m = 3:49.40; 3000 m = 8:37.00; Female: 800 m = 2:15.45; 1500 m = 4:41.4; 3000 m = 10:03.80). The *Prov* group consisted of 12, 15, and 7 athletes from the 800, 1500, and 3000 m events, respectively. The *Club* group was comprised of 16 athletes (14 males and 2 females) who had run a performance time that was within 15% of the Olympic Trials qualifying standard (Male: 800 m = 2:09.37; 1500 m = 4:22.20; 3000 m = 9:26.26; Female: 800 m = 2:28.35; 1500 m = 5:08.20; 3000 m = 11:01.37). The *Club* group consisted of 2, 7, and 7 athletes, from the 800, 1500, and 3000 m events, respectively. The current mean ages of the three groups in the study were as follows: *Nat* = 25.45 ± 3.8 years; *Prov* = 21.64 ± 3.2 years; and *Club* = 20.2 ± 3.0 years.

<u>Procedure.</u> All participants received a questionnaire asking them to consider various dimensions of their current training. The first part of the questionnaire pertained to biographical

information, e.g., their age, primary track event, and whether the athlete was currently training and competing. The second part of the questionnaire asked the participants to rate their practice activities based on their current perceptions of training. Through extensive pilot work with athletes and coaches, a list of 12 track training activities, eight track-related activities, and seven everyday activities was conceived for the questionnaire (see Table 1). Participants were asked to

Table 1. Activity Lists Presented in the Ratings Questionnaire.

Track Activities	Track-Related Activities	Everyday Activities
Cross Training *(CT)*	Conversation about Running *(CAR)*	Active Leisure *(AL)*
Flexibility *(Flex)*	Coaching Track to Others *(CTO)*	Non-active Leisure *(NAL)*
Mental Preparation *(MP)*	Diet/Nutritional Planning *(Diet)*	Eating/Snacking *(Eat)*
Easy Run *(Easy)*	Physiotherapy *(Phys)*	Sleeping *(Sleep)*
Hard/Tempo Run *(H/TR)*	Reading Running Material *(Read)*	Study/Work *(SW)*
Long Interval Work *(LIW)*	Training Journal *(Journ)*	Traveling/Commuting *(Trvl)*
Short Interval/Speed Work *(SIW)*	Organization and Preparation *(O&P)*	Body Care and Health *(Body)*
Race/Time Trial *(Race)*	Watching Running *(Watch)*	
Technique *(Tech)*		
Power Weights *(PW)*		
Endurance Weights *(EW)*		
Work with a Coach *(WwC)*		

Note. The activity labels for Figures 1-8 are italicized and presented in brackets.

rate each of the activities on the four DP dimensions using a scale from 0-10. First, they were asked to rate the relevance of the activity for improving performance in middle distance track. Second, they were asked to rate the effort required to perform the activity. Third, they were asked to rate how enjoyable their participation in the activity was without considering possible consequences of the activity. Finally, they were asked to rate the degree of concentration, or mental effort, required to perform the activity.

Results for Track Activities

Comparison of Activity Ratings between Performance Groups

The ratings for the 12 track activities were analyzed for the different performance groups (*Nat, Prov, Club*) and dimensions (relevance, effort, concentration, enjoyment) using a multivariate analysis of variance (MANOVA). There were no significant differences between the groups for activity ratings, $F(2, 78) = .085$, $p = .610$.

Comparison of Ratings between Track Activities Collapsed across the Three Performance Groups

Since the MANOVA found no significant differences between the performance groups, the activity ratings were then collapsed across all three groups for the purpose of defining DP in middle distance running. Concurrent with previous research (Ericsson et al., 1993; Helsen et al., 1998; Hodges & Starkes, 1996), a grand mean of activity ratings was calculated for each dimension of relevance, effort, concentration, and enjoyment. Next, t-tests compared the individual activity rating means to the respective grand mean for each dimension. Measures of significance were based on an adjusted alpha level using the corrected Bonferroni ($p = 0.0042$).

Finally, those activities which fulfilled Ericsson et al.'s (1993) criteria for DP, i.e., those activities that were significantly higher than the grand dimension means for relevance and effort, but significantly lower than grand enjoyment mean, were identified. Concurrently, those activities that fulfilled additional sport-modified criteria for DP (Helsen et al., 1998; Hodges & Starkes, 1996), i.e., those that were rated significantly higher than the grand dimension means for concentration and enjoyment, were also recorded.

In terms of perceived relevance of an activity for improving middle distance running performance, Figure 1 indicates that participants rated five of the 12 track activities significantly higher than the grand relevance mean. *Short Interval Work/Speed* was given the highest relevance rating by 57 of the 81 participants. *Race/Time Trial*, *Long Interval Work*, *Hard/Tempo Run*, and *Easy Run* also received significantly higher ratings for relevance. A sixth activity, *Mental Preparation*, was judged to be higher than the grand relevance mean at a statistical level approaching significance, $p = .097$. In terms of the perceived physical effort required to perform an activity (Figure 2), *Race/Time Trial*, *Short Interval Work/Speed*, *Long Interval Work*, *Hard/Tempo Run*, and both weight training activities were all rated significantly higher than the grand effort mean. In terms of concentration required to perform an activity (Figure 3), *Race/Time Trial* was rated as the activity that requires the most mental effort to perform.
In addition to *Race/Time Trial*, other activities that were rated significantly higher than the grand concentration mean included *Mental Preparation*, *Short Interval Work/Speed*, and *Long Interval Work*. For perceived inherent enjoyment of an activity (Figure 4), participants rated four of the

12 activities significantly higher than the grand enjoyment mean - *Race/Time Trial*, *Easy Run*, *Short Interval Work/Speed*, and *Work with a Coach*. Conversely, three activities were rated significantly lower than the grand enjoyment mean. These activities included *Flexibility*, *Power Weights*, and *Technique*.

In the present study, it is important to note that the 12 track practice activities were analyzed separately from the 15 track-related and everyday activities. This approach presumably resulted in a more discriminating analysis than previous research (Ericsson et al., 1993; Helsen et al., 1998; Hodges & Starkes, 1996) in which all three categories of activities were amalgamated, thereby deflating the grand dimension means and lending more susceptibility to finding significant differences for the respective means.

Relationships between the Dimensions of DP

Pearson correlations were used to examine the relationships between the dimensions of relevance, effort, enjoyment, and concentration for the track practice activities. Results revealed that concentration and effort ($r = .657$, $n = 79$, $p < .05$) were most highly correlated. Significant positive relationships ($n = 79$, $p < .05$) were also found between relevance and concentration ($r = .581$), relevance and effort ($r = .493$), relevance and enjoyment ($r = .424$), effort and enjoyment ($r = .370$), and concentration and enjoyment ($r = .226$).

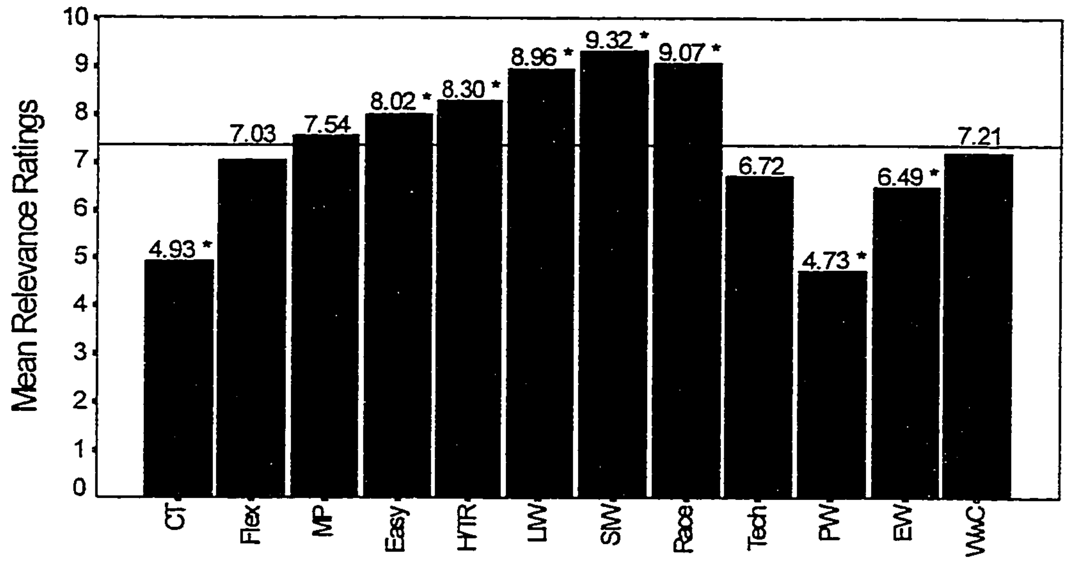

Figure 1. Mean relevance ratings for track practice activities collapsed across three performance groups. The horizontal line represents the grand dimension mean (M = 7.36). Significant differences from the dimension mean are at p = .0042 and denoted by an asterisk.

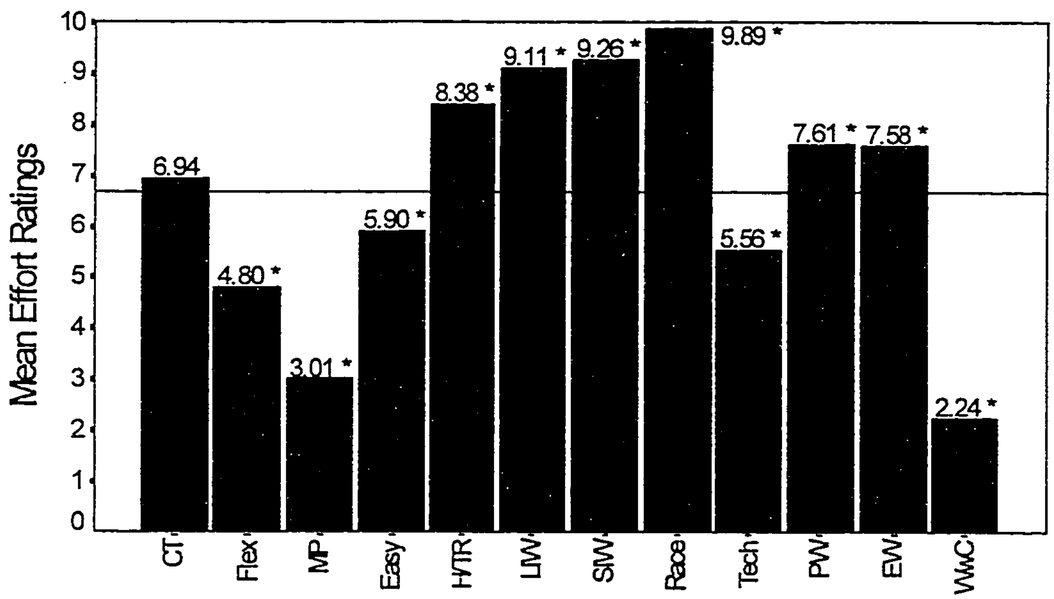

Figure 2. Mean effort ratings for track practice activities collapsed across three performance groups. The horizontal line represents the grand dimension mean (M = 6.69).

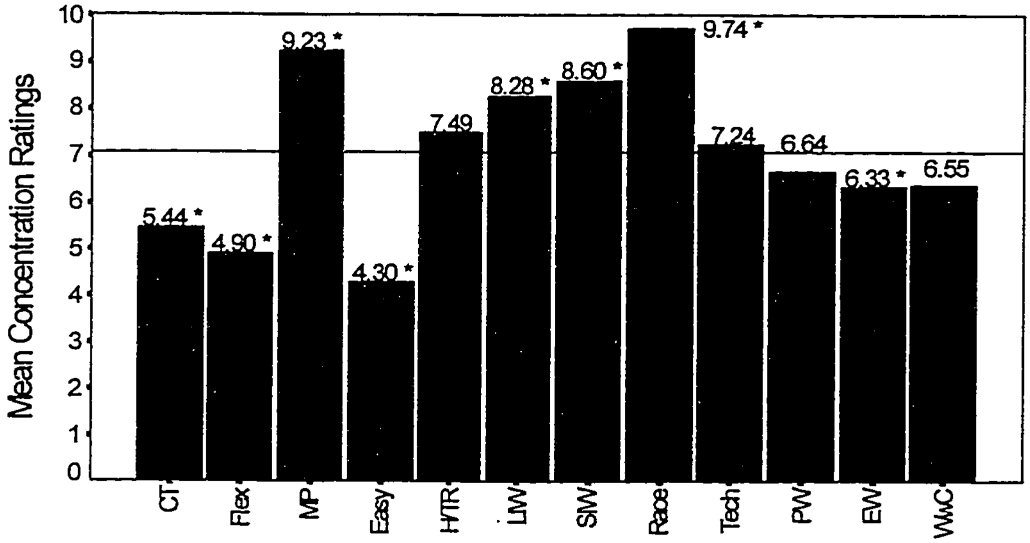

Figure 3. Mean concentration ratings for track practice activities collapsed across performance skill groups. The horizontal line represents the grand dimension mean (M = 7.06).

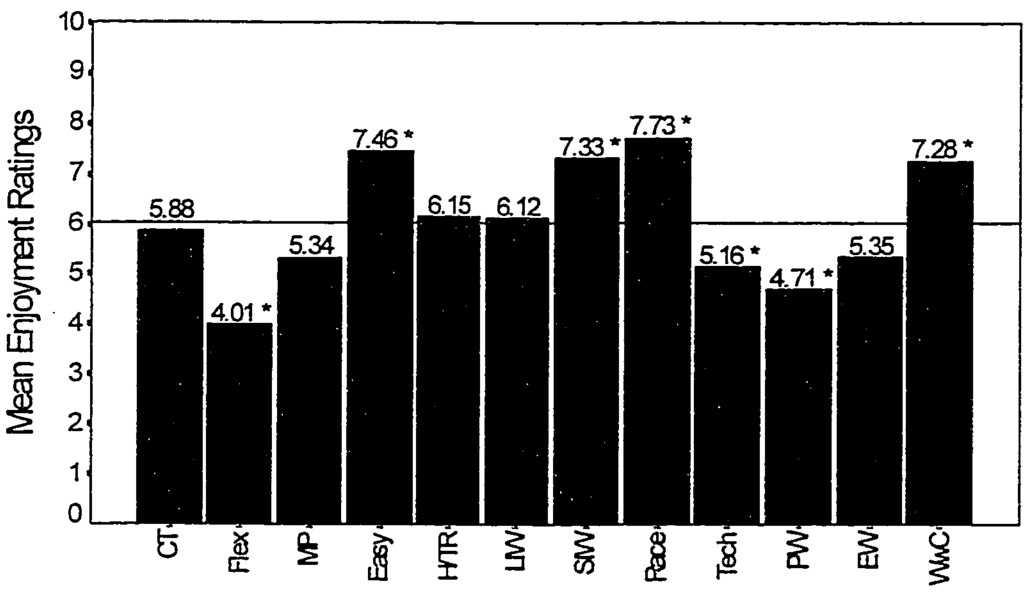

Figure 4. Mean enjoyment ratings for track practice activities collapsed across three performance groups. The horizontal line represents the grand dimension mean (M = 6.05).

Results for Track-Related and Everyday Activities

Comparison of Track-related and Everyday Activity Ratings between Performance Groups

The ratings for the 15 track-related and everyday activities were analyzed for the different performance groups (*Nat*, *Prov*, *Club*) and dimensions (relevance, effort, concentration, enjoyment) using a MANOVA. The MANOVA revealed no significant differences between the groups for activity ratings, $F(2, 69) = .529$, $p = .197$.

Comparison of Ratings between Track-Related and Everyday Activities Collapsed across the Three Performance Groups

As for the track activities, a grand mean of activity ratings was calculated for each dimension of relevance, effort, concentration, and enjoyment for the repertoire of track-related and everyday activities. Again, t-tests were used to compare individual activity rating means to the respective grand mean for each dimension. Significance levels were also based on an adjusted alpha ($p = 0.0033$).

In terms of relevance for improving middle distance running performance, Figure 5 indicates that the participants rated four of the 15 track-related and everyday activities significantly higher than the grand relevance mean - *Sleeping*, *Training Journal*, *Diet/Nutritional Planning*, and *Eating*. In terms of perceived effort (Figure 6), *Study/Work*, *Active Leisure*, and *Coaching Track to Others* were all rated significantly higher than the grand effort mean. Conversely, *Watching Running*, *Sleeping*, *Conversation about Running*, *Reading about Running*, *Non-active Leisure*, and *Eating* activities were all judged to be significantly lower than the grand effort mean. In terms of concentration (Figure 7), *Study/Work*, *Coaching Track to Others*, *Diet/Nutritional Planning*, and *Training Journal* were all rated significantly higher than the grand concentration mean. *Sleeping, Eating, Non-active Leisure, Traveling/Commuting*, and *Watching Running* were rated significantly lower than the grand concentration mean. Finally, for the perceived inherent enjoyment of an activity (Figure 8), participants rated six activities significantly higher than the grand enjoyment mean - *Sleeping, Watching Running, Active Leisure, Non-active Leisure, Eating*, and *Conversation about Running*. *Sleeping* was judged to be the most enjoyable of all the track-related and everyday activities.

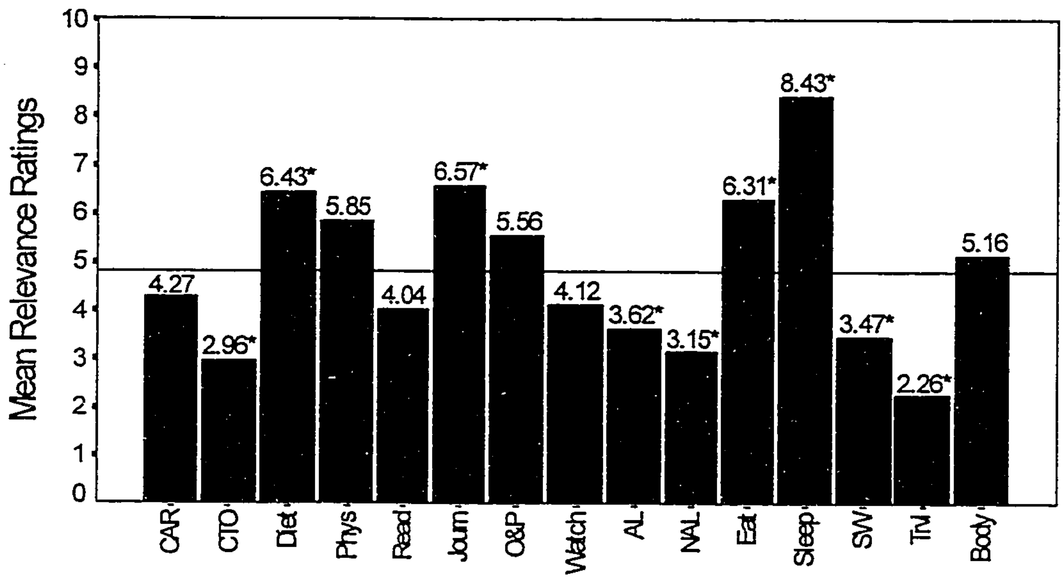

Figure 5. Mean relevance ratings for track-related and everyday activities collapsed across three performance groups. The horizontal line represents the grand dimension mean ($M = 4.82$). Significant differences from the dimension mean are at $p = .0033$ and denoted by an asterisk.

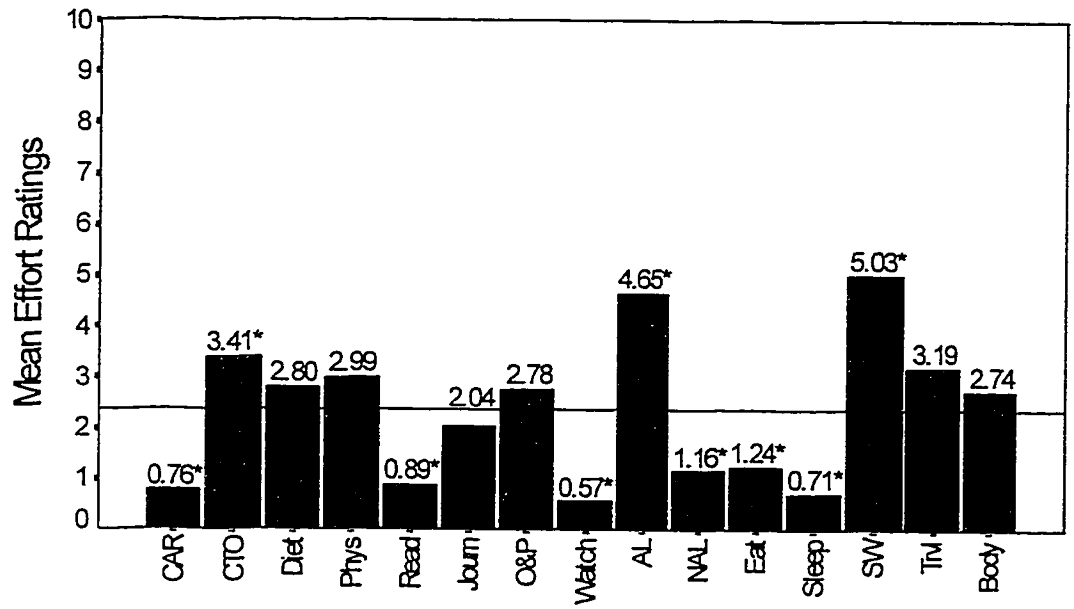

Figure 6. Mean effort ratings for track-related and everyday activities collapsed across three performance groups. The horizontal line represents the grand dimension mean (M = 2.38).

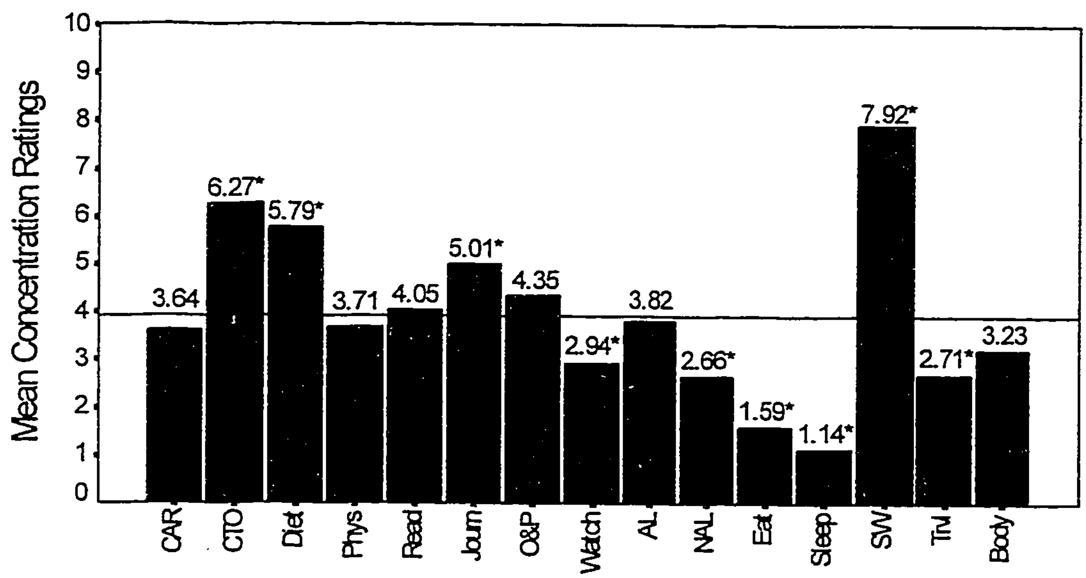

Figure 7. Mean concentration ratings for track-related and everyday activities collapsed across three performance groups. The horizontal line represents the grand dimension mean (M = 3.92).

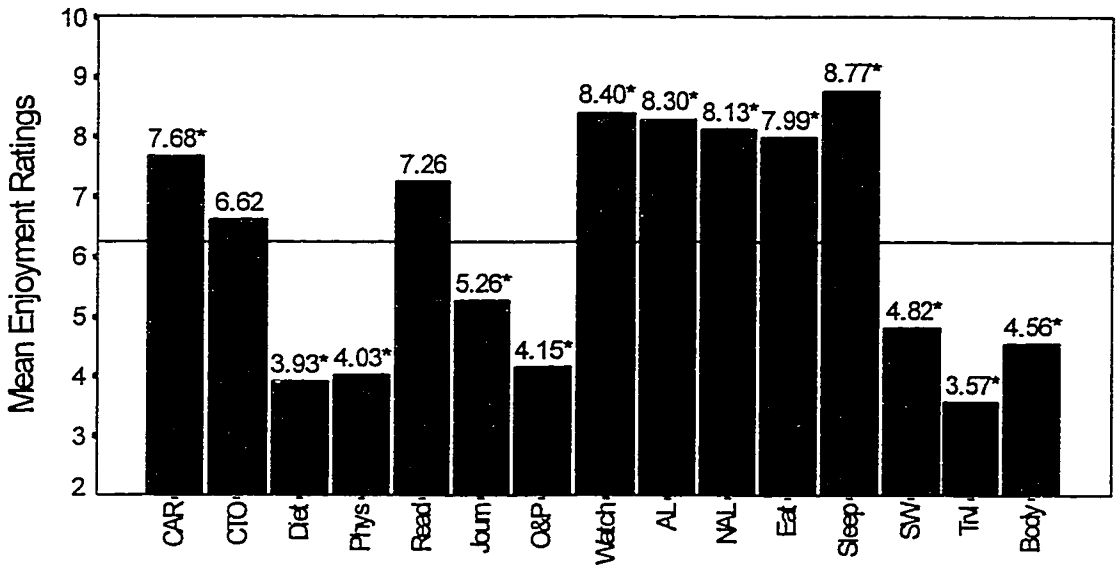

Figure 8. Mean enjoyment ratings for track-related and everyday activities collapsed across three performance groups. The horizontal line represents the grand dimension mean (M = 6.24).

Discussion

One of the purposes of this study was to examine whether elite athletes perceived specific training activities in a different manner than their lesser counterparts. If so, then differential perceptions could ultimately result in different emphases within each performance group's respective training environment. This logic is based on the assumption that an athlete will place more emphasis on activities rated most relevant to improving performance. The present analysis revealed that the national, provincial, and club level runners shared similar perceptions of their current practice. More importantly, all three performance groups seemed to consider the same set of practice activities as most relevant for improving performance in middle distance running, thereby corroborating previous findings in the domains of music (Ericsson et al., 1993) and sport (Helsen et al., 1998; Hodges & Starkes, 1996). If athletes of different performance levels perceive training in the same manner, then, consequentially, the question is whether this parity in perception is reflected in actual amounts of participation: do expert athletes actually do more of these highly relevant activities (Young & Salmela, 1998)?

The underlying motive for analyzing the activity ratings was to identify DP for middle distance running and, in doing so, to identify a select group of activities deemed most relevant for improving performance in the sport. Our analyses compared individual activity ratings against a grand mean for each of the four dimensions (relevance, effort, concentration, and enjoyment) and, thus, presented an opportunity to test Ericsson et al.'s (1993) definition of DP. In previous research, an activity was perceived as relevant if it mirrored the demands of the ultimate performance environment, or in sport, the ultimate competitive environment. In instrumental music, for example, activities such as practicing alone with the violin or solo performances, were reliably judged as the most relevant form of practice. In wrestling, mat work, or sparring with a partner, was rated as the most relevant practice activity (Hodges & Starkes, 1996). In soccer and field hockey, training activities that recreated game conditions and tactics were perceived as extremely relevant for improving performance (Helsen et al., 1998). In the present study, only activities that required the actual motor activity of running, e.g., easy-paced runs, up-tempo runs, long interval and speed work, races and time trials, were rated as extremely relevant.

Interestingly, activities that would seemingly elicit similar physiological effects to running, e.g., cross training, were perceived as significantly lower than the grand relevance mean. These findings provided further evidence of the remarkable domain-specificity embodied by the most relevant forms of training, and thus, the definition of DP. Although it does not involve motor activity, a notable sixth training activity, mental preparation, was rated higher than the grand dimension mean for relevance at a level approaching significance.

Another main finding was that the most relevant practice activities were also judged to be very enjoyable. The runners considered speed work and time trials, the two most highly rated activities for relevance, to be significantly enjoyable compared to the grand dimension mean. For track practice activities, the dimension of relevance was highly correlated with enjoyment. Training activities that involve race-related skills and tactics, and, therefore, imitate the ultimate competitive environment appeared to be perceived as enjoyable. These trends parallel findings in other sport settings (Helsen et al., 1998; Hodges & Starkes, 1996) and are in contrast to the definition of DP initially proposed by Ericsson et al. (1993).

A third important finding was that the practice activities rated most highly for effort were also perceived to be highly enjoyable. The two most effortful practice activities, races and time trials, and speed work, were also rated significantly higher than the grand mean for enjoyment. What has emerged is a view of DP as relevant and effortful training, yet seemingly enjoyable as well. Ericsson's (1996) rebuttal for the potential enjoyment factor for DP focused on the argument that practice in sport is inherently social and it is this social aspect that individuals perceive as enjoyable, as opposed to the practice itself. Unlike team sports where this explanation may well apply, running is primarily an individual sport and training often occurs alone, thus, alternative explanations must be advanced to account for the current findings. The next section discusses several of these proposed alternatives.

First, the ratings for enjoyment may reflect the participants' motivation to reduce cognitive dissonance (Festinger, 1957) arising from two conflicting conceptions of practice. The reported ratings may represent expressed, rather than genuine perceptions. In this study, the participants rated the most highly effortful activities as the most enjoyable forms of practice. Yet, conflicting evidence from physiological studies and athletes' self-reports suggests that these same forms of effortful training can be uncomfortable. These track athletes have voluntarily chosen to engage in long-term periods of systematic training, which is quite a remarkable feat in the absence of external rewards and incentives in this sport. Possibly, insufficient justification (Festinger & Carlsmith, 1959) for their arduous and painstaking training has compelled them to inflate their ratings of enjoyment for the most effortful activities.

Second, from a psycho-biological perspective, the phenomenon of running addiction may explain the perception of enjoyment during practice. Dishman (1982), Sachs (1978, 1991), and Pargman and Burgess (1977) have speculated that runners become addicted or dependent upon their exercise experiences. Biochemical influences that accompany vigorous exercise have been implicated in positive shifts in mood (Dishman, 1982; Markoff, Ryan, & Young, 1982). These altered biochemical conditions result in an increased threshold for the subjective "runner's high" and an increased severity of withdrawal symptoms. Running workouts fit classic models of the addictive cycle, in which opposing pleasurable and unpleasurable states correspond to altered conditions of body chemistry (Dishman, 1982; Hatfield, 1991). Opponent-process theory (Solomon, 1977) may represent another psychological explanation for exercise-induced affect during effortful practice (Hatfield, 1991). According to this conceptual framework, psychological processes interact dynamically such that an opposing, or unpleasant, state follows engagement in any pleasurable activity. It is well documented that withdrawal symptoms intensify as a function of elapsed post-running time (Carmack & Martens, 1979; Morgan, 1979; Sacks, 1981). By induction, the prevalence of these unpleasant withdrawal stressors following the termination of running practice suggests the existence of a preceding enjoyable stimulus, i.e., running practice.

Another potential explanation for athletes' seeming enjoyment of DP could stem from their own evaluations of their performance during practice. Certainly, a runner will associate pleasure with the consequences of their effortful practice, such as the completion of a challenging workout, or the knowledge that what they are doing in practice is ultimately improving their fitness. However, it may be sensible to recognize the existence of psychological processes and that are concurrent with vigorous exercise which effectively result in perceptions of enjoyment during the practice bout. From a pragmatic perspective, the sole goal of these middle distance athletes is to run fast. Therefore, any practice activity that can elicit the perception of "feeling fast" will be interpreted as enjoyable. This feeling can be perceived during time trials or speed work if athletes evaluate their performance during practice to be consonant with, or relatively closer to their desired competitive condition. A desired competitive condition may be synonymous with an athlete's optimal kinesthetic feeling, and/or knowledge of results, such as split times, or biofeedback, such as heart rate. In running, split times are provided during practice, and this feedback can confirm positive kinesthetic evaluations and reinforce perceptions of enjoyment. This "feel fast" perception, if deemed to be highly robust and resistant to decay, could explain athletes' persistent belief in relatively enjoyable practice even when confronted with consecutively poor, or "feel bad," practices. Unlike the unconscious psychological processes related to the "flow" experience (Csikszentmihalyi, 1990), this speculative "feel fast" perception is based on the conscious evaluation of one's performance during practice and is, therefore, acceptable within the constraints of the DP framework.

It appears that athletes may enjoy practice for different reasons depending on the perceived effort of practice. Both highly effortful activities, such as races, time trials, and speed work, and low effort activities, for example, easy-paced runs and working with a coach, were perceived as enjoyable. It is possible that low effort activities are rated as pleasurable for their play or social characteristics. An easy-paced run would seem to embrace the more aesthetic elements of running, for example, "being at one with nature", and could potentially be equated with play. The runners' perceived enjoyment for working with their coach may have reflected socially desirable attributes associated with the establishment of cooperative or intimate relationships. Although the athletes' motives for enjoyment remain unclear, it appears that Ericsson et al.'s (1993) enjoyment construct needs to be reconsidered for practice in sport.

Previous research on the nature of DP in sport revealed that concentration is a separate factor from effort (Helsen et al., 1998; Hodges & Starkes, 1996). In the present study, this distinction was particularly evident for mental preparation activities: the athletes perceived mental preparation as requiring very little physical effort, yet also rated these same exercises highly for amounts of concentration. To a lesser degree, technique work, weights, and cross training, exhibited distinctions between the two dimensions.

One of the primary objectives of the present research was to identify activities that constitute DP for middle distance running. In order to compile a list of DP activities, the current findings were scrutinized according to the criteria indigenous to the definition of DP for music (Ericsson et al., 1993). According to these criteria, i.e., those activities that were significantly higher than the grand dimension means for relevance and effort, but significantly lower than the grand enjoyment mean, no activities in the current study would have qualified as DP for middle distance running. This would appear preposterous - the activity lists were comprehensive and certainly included activities that were most adequate for deliberately improving runners' performance. It would seem more likely that the initial unmodified definition of DP (1993) was not applicable to middle distance running.

Instead, a sport-specific modification of Ericsson et al.'s (1993) construct was implemented in order to identify DP for middle distance running. According to this new version, five activities qualified as DP: hard up-tempo runs; long interval work; speed work; races and time trials; and mental preparation activities. Each of these five practice activities was judged to be higher than the grand relevance mean at a level of statistical significance, or approaching statistical significance. Each of the five practice activities was either rated significantly higher than the grand effort mean, or rated significantly higher than the grand concentration mean. The current sport-modified version respected two concessions that were specific to running. First, the present criteria coincided with previous sport scientists (Helsen et al., 1998; Hodges & Starkes, 1996) call for including a fourth dimension for concentration and confirmed that this dimension was indeed separate from physical effort, particularly for activities designed for purposes of mental performance enhancement. Thus, DP for middle distance running consisted of activities that exhibited high ratings for both concentration and effort, but in the case of mental preparation, high ratings for concentration only. Second, the present findings accentuated the fact that DP is seemingly enjoyable in middle distance running. Due to the fact that these findings run contrary to the initial definition of DP for music (Ericsson et al., 1993), it is questionable as to whether the enjoyment dimension can be transferred across domains. Certainly, it was unclear whether it should be retained as a discriminating dimension for the definition of DP in middle distance running - future research is needed to resolve this matter. Thus, for practical purposes, enjoyment was not used as a defining criterion for the sport-specific conception of DP for middle distance running.

Another purpose of the present research was to identify activities that facilitated recovery from the effortful demands of training, and, therefore, could be considered relevant for improving running performance. In the present study, our analysis of everyday activities identified two remarkable recovery activities. Sleeping and eating were perceived to be both enjoyable and highly relevant for improving performance, yet were significantly low on dimensions of effort and concentration. The athletes' perceptions indicated that these activities were conscious attempts to conserve resources outside of training and, therefore, to facilitate physical and mental regeneration. By the same logic, studying and working, coaching track to other people, and engaging in active leisure, all appeared to compete for resources during regeneration and were, therefore, counterproductive to an efficient recovery. The participants judged two track-related exercises - planning their diet and nutrition regimen, and maintaining and consulting their training journal, to be also highly relevant for improving their performance. These track-related and everyday activities, although not considered as practice per se, were judged as activities intended to improve performance in middle distance running.

Conclusion

Ericsson et al. (1993) posited that DP, as a construct that is inherently enjoyable, is transferable across domains. The findings from this study challenged the generalizability of this DP definition and suggested that concessions should be recognized for its application in sport. The sport commitment model (Carpenter et al., 1993; Scanlan et al., 1993a, 1993b) has revealed that sport enjoyment is an antecedent variable dictating athletes' initial participation in sport. If, as the present findings suggested, relevant practice is enjoyable, then the very nature of DP may facilitate athletes' continued commitment and persistence in sport. Evidently, future research is necessary in regards to the enjoyment dimension and hedonic states associated with DP in sport.

According to a modified conception of DP for middle distance running, DP was perceived by the runners as activities that are highly relevant for improving performance, and which require either great amounts of physical effort or high levels of concentration.

References

Athletics Canada. (1996). Olympic Trials qualifying standards. Ottawa: Athletics Canada.

Bloom, B.S. (1985). Generalizations about talent development. In B.S. Bloom (Ed.), Developing talent in young people (pp.507-549). New York: Ballantine.

Carmack, M.A., & Martens, R. (1979). Measuring commitment to running: A survey of runner's attitudes and mental states. Journal of Sport Psychology, 1, 25-42.

Carpenter, P.J., Scanlan, T.K., Simons, J.P., & Lobel, M. (1993). A test of the sport commitment model using structural equation modeling. Journal of Sport and Exercise Psychology, 15, 119-133.

Charness, N., Krampe, R.Th., & Mayr, U. (1996). The role of practice and coaching in entrepreneurial skill domains: An international comparison of life-span chess skill acquisition. In K.A. Ericsson (Ed.), The road to excellence: The acquisition of expert performance in the arts and sciences, sports and games (pp.51-80). Mahwah, NJ: LEA.

Chase, W.G., & Simon, H.A. (1973). The mind's eye in chess. In W.G. Chase (Ed.), Visual information processing (pp.215-281). San Diego, CA: Academic Press.

Csikszentmihalyi, M. (1990). Flow: The psychology of optimal experience. New York: Harper & Row.

Dishman, R.K. (1982). Compliance/adherence in health-related exercise. Health Psychology, 1 (3), 237-267.

Ericsson, K.A. (1996). The acquisition of expert performance: An introduction to some of the issues. In K.A. Ericsson (Ed.), The road to excellence: The acquisition of expert performance in the arts and sciences, sports, and games (pp.1-50). Mahwah, NJ: LEA.

Ericsson, K.A. (1997). The acquisition of expert performance: Insights into optimal improvement through deliberate practice. A presentation at the annual meeting of the Canadian Society for Psychomotor Learning and Sport Psychology. Niagara Falls, ON.

Ericsson, K.A., Krampe, R.Th., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. Psychological Review, 100(3), 363-406.

Festinger, L. (1957). A theory of cognitive dissonance. Stanford, CA: Stanford University Press.

Festinger, L., & Carlsmith, J.M. (1959). Cognitive consequences of forced compliance. Journal of Abnormal and Social Psychology, 58, 203-210.

Glover, B., & Schuder, P. (1988). The new competitive runner's handbook. New York: Penguin Books.

Hatfield, B. (1991). Exercise and mental health: The mechanisms of exercise-induced psychological states. In L. Diamant (Ed.), Psychology of sports, exercise, and fitness. New York: Hemisphere.

Hagan, R.D., Smith, M.G., & Gettman, L.R. (1981). Marathon performance in relation to maximal aerobic power and training indices. Medicine and Science in Sports and Exercise, 13, 185-189.

Hodges, N.J., & Starkes, J.L. (1996). Wrestling with the nature of expertise: A sport specific test of Ericsson, Krampe and Tesch-Römer's (1993) theory of deliberate practice. International Journal of Sport Psychology, 27, 400-424.

Kalinowski, A.G. (1985). The development of Olympic swimmers. In B.S. Bloom (Ed.), Developing talent in young people (pp.139-192). New York: Ballantine.

Krampe, R.Th. (1994). Maintaining excellence: Cognitive-motor performance in pianists differing in age and skill level. Berlin: Max-Planck-Institut fur Bildungforschung.

Krampe, R.Th., & Ericsson, K.A. (1996). Maintaining excellence: Deliberate practice and elite performance in young and older pianists. Journal of Experimental Psychology: General, 125(4), 331-359.

Markoff, R.A., Ryan, P., & Young, T. (1982). Endorphins and mood changes in long-distance running. Medicine and Science in Sports and Exercise, 14, 11-15.

Mercier, D., & Beauregard, S. (1994). Mercier scoring tables. Ottawa: Athletics Canada.

Monsaas, J.A. (1985). Learning to be a world-class tennis player. In B.S. Bloom (Ed.), Developing talent in young people (pp.211-269). New York: Ballantine.

Morgan, W.P. (1979). Negative addiction in runners. The Physician and Sportsmedicine, 7, Feb.,57-70.

Noakes, T. (1991). Lore of running: Discover the science and spirit of running. Champaign, IL: Leisure Press.

Pargman, D., & Burgess, S. (1977). Hooked on exercise: A psychobiological explanation. Paper presented at the annual meeting of the North American Society for the Psychology of Sport and Physical Activity. Ithaca, New York.

Sachs, M.L. (1978). Exercise addiction. Racing South, 1(3), 14-16.

Sachs, M.L. (1991). Running - A psychosocial phenomenon. In L. Diamant (Ed.), Psychology of sports, exercise, and fitness (pp.237-248). New York: Hemisphere.

Sack, H.-G. (1980). The psychology of elite adolescent athletes: A longitudinal study of male and female long-distance runners over a period of four years towards the end of adolescence. Schondorf: Hofmann.

Sacks, M.H. (1981). Running addiction: A clinical report. In M.H. Sacks & M.L. Sachs (Eds.), The psychology of running (pp. 127-130). Champaign, IL: Human Kinetics.

Scanlan, T.K., Carpenter, P.J., Schmidt, G.W., Simons, J.P., & Keeler, B. (1993a). An introduction to the sport commitment model. Journal of Sport and Exercise Psychology, 15, 1-15.

Scanlan, T.K., Simons, J.P., Carpenter, P.J., Schmidt, G.W., & Keeler, B. (1993b). The sport commitment model: Measurement development for the youth-sport domain. Journal of Sport and Exercise Psychology, 15, 16-38.

Sloboda, J.A. (1996). The acquisition of musical performance expertise: Deconstructing the "talent" account of individual differences in musical expressivity. In K.A. Ericsson (Ed.), The road to excellence: The acquisition of expert performance in the arts and sciences, sports and games (pp.107-126). Mahwah, NJ: LEA.

Solomon, R.L. (1977). An opponent process theory of motivation: The affective dynamics of drug addiction. In J.D. Maser & M.E.P. Seligman (Eds.), Psychopathology: Experimental models (pp.66-103). San Francisco, CA: W.H. Freeman and Co.

Starkes, J.L. (in press). The road to expertise: Is practice the only variable? International Journal of Sport Psychology.

Wallingford, R. (1975). Long distance running. In A.W. Taylor (Ed.), The scientific aspects of sport training (pp.118-130). Springfield, IL: Charles C Thomas.

Young, B.W., & Salmela, J.H. (1998). Deliberate practice and the acquisition of expert performance in Canadian middle distance running. Unpublished master's thesis, University of Ottawa.

ARTICLE 2

Deliberate Practice and the Acquisition of Expert Performance in Canadian Middle Distance Running

Abstract

This study tested Ericsson, Krampe, and Tesch-Römer's (1993) framework for the acquisition of expertise according to a modified conception of deliberate practice for middle distance running (Young & Salmela, 1998). Retrospective analyses compared accumulated amounts of deliberate practice, accumulated practice in all track activities, and accumulated kilometers run between national, provincial, and club level runners across the initial nine years of their careers. Attained performance levels were governed by a monotonic relationship with accumulated practice variables in accordance with the power law of practice (Anderson, 1982; Newell & Rosenbloom, 1981). Hierarchical regressions explained variance in running performance as accounted for by accumulated practice variables. Practice early in a career proved to be a far better predictor of eventual running performance than a natural talent construct. The formative role of a coach early in the runners' careers was demonstrated, thereby lending further credibility to the entrenchment of supervised instruction into the sport-specific definition of deliberate practice.

Key Words: Deliberate practice, Expertise, Running

No one would underestimate the utility of practice for improving real life skills, nor would one likely deny that practice plays a mediating role in the acquisition of expert level performance. Yet, there would seem to be much opposition to the claim that practice is the foremost mediator of expertise. Ericsson, Krampe and Tesch-Römer (1993) embraced this extreme environmental position when they proposed a framework for the acquisition of expertise, based primarily on the concept of deliberate practice. Their theoretical framework discounted any determining role of "natural talent" or innate characteristics in the development of exceptional performance.

Ericsson and colleagues (Ericsson, 1996; Ericsson et al., 1993) preferred to subscribe to the underlying assumption that expertise was the extreme outcome of long-term adaptation to the constraints of a specific domain. The most important constraint was the need for extensive training within that domain - typically a "10 year rule of preparation" (Bloom, 1985; Charness, Krampe, & Mayr, 1996; Ericsson et al., 1993; Gustin, 1985; Heisen, Starkes, & Hodges, 1998; Hodges & Starkes, 1996; Patel, Kaufman, & Magder, 1996; Sosniak, 1985;) or 10,000 hours of goal-directed practice (Simon & Chase, 1973) were invoked as necessary conditions for the acquisition of exceptional performance. However, these were not sufficient prerequisites: merely engaging in maximal amounts of practice did not lead to maximal performance. The theoretical framework (Ericsson, 1996; Ericsson et al., 1993) postulated that participation in the most relevant forms of training was most effective for acquiring expertise.

Deliberate practice (DP) was initially identified as training activities that were most relevant for improving performance in a domain and that consisted of highly effortful, but not inherently enjoyable activities (Ericsson et al., 1993). However, seminal research in sport has modified the defining criteria for DP somewhat. According to athletes' perceptions of their training, DP consisted of activities that were very relevant for improving performance and very effortful, but it also consisted of activities in which participation was relatively enjoyable. (Helsen et al., 1998; Hodges & Starkes, 1996). An added dimension to the sport-specific DP construct was that it also required high levels of concentration. According to a modified conception of DP for middle distance running (Young & Salmela, 1998), DP was perceived by runners as activities that were highly relevant for improving performance, and which required either great amounts of physical effort or high levels of concentration. This modified conception of DP refrained from using enjoyment as a discriminating dimension for the identification of domain-specific DP.

The central thesis of Ericsson's framework stated that "practice makes expert" - expert performance was primarily the result of an extended process of acquisition mediated by large amounts of DP (Ericsson et al., 1993). At any point in a career, individual differences in performance were a function of acquired characteristics, which in turn were directly related to accumulated amounts of DP. A "monotonic benefits assumption" dictated that differences in the accumulation of DP reliably accounted for both inter-individual and expert-novice differences in performance. Furthermore, the monotonic relationship dictated that differences in accumulated DP reliably accounted for many of the physiological differences distinguishing elite performers in sport (Ericsson, 1997; Ericsson, 1996; Ericsson et al., 1993). The practice-performance relationship obeyed the inverse power law of practice (Newell & Rosenbloom, 1981), such that each incremental improvement in performance required an additional log unit of practice (Anderson, 1982; Ericsson et al., 1993; Newell & Rosenbloom, 1981).

Ericsson et al. (1993) first tested their DP framework by investigating a sample of violinists who had starting practicing the violin at the same age and who had formal training for longer than 10 years. The investigators contrasted measures between three performance groups: "best" violinists, "good" violinists, and "lower criteria" violinists. The musicians were asked to retrospectively estimate weekly amounts of practice for each year since they had started playing the violin. These estimates, in turn, were converted to annual and accumulated career totals. Results indicated that time spent practicing alone increased in a monotonic fashion: there was complete correspondence between acquired performance level and accumulated amounts of practice alone with the violin. By the age of 18, the best group had engaged in significantly more practice alone than the good and lower criteria violinists; the best violinists had accumulated significantly more practice alone than the lower criteria group. Trends indicated that the best violinists had practiced more during the earlier years, particularly at the age of 15 years, in comparison to the good group.

These results were similarly replicated in a second study with expert and amateur pianists (Ericsson et al., 1993; Krampe, 1994). Investigators derived weekly amounts of practice from the performers' biographical estimates and then calculated annual totals and accumulated totals for each year of their life. Results indicated that expert pianists practiced significantly more than amateurs for each year of life, except at the age of five.

For amounts of accumulated practice as a function of age, the expert pianists had engaged in substantially more accumulated amounts of practice than their amateur counterparts by the age of 18.

Evidently, there is initial support for the DP expertise theory in the domain of music. Two recent studies have specifically tested the DP framework in sport. Hodges and Starkes (1996) examined international and club level wrestlers who began the sport at similar ages and who had practiced for the requisite 10 years. The wrestlers retrospectively recalled weekly amounts of practice at the start of their career and for every three years onward. Weekly estimates were then converted to annual and accumulated career totals. Results showed that international wrestlers devoted more time to practice than their club level counterparts as early as three years into their careers, with this trend becoming more pronounced further into their respective careers. Results revealed no significant differences between the performance groups for accumulated amounts of wrestling practice alone, however, there was a significant difference between the performance groups for accumulated practice with others.

Helsen and colleagues (1998) undertook similar research with international, national, and provincial level field hockey and soccer players. Again, athletes were asked to retrospectively recall amounts of weekly practice at different intervals across their careers. Like the previous studies, amounts of weekly practice were translated into accumulated totals across their careers. Results indicated that the "10 year rule of preparation" was a valid construct: beyond nine years into a career international-level players began to commit more investment into training compared to their lesser counterparts. The monotonic relationship between accumulated amounts of DP and eventual level of performance was demonstrated. For both the hockey and soccer samples, the international group had accumulated the most DP across their career; the national players had accumulated more DP than their provincial-calibre peers. Based on seminal research in wrestling, field hockey, and soccer, it would appear that the DP framework for the acquisition of expertise is substantiated in sport.

Extant research in the sport of running has suggested a main effect of performance level on the frequency, amount, and intensity of practice (Hagan, Smith, & Gettman, 1981; Noakes, 1991; Sack, 1980). Championship competitors devoted significantly more time to practice and covered longer running distances than their advanced and basic counterparts (Glover & Schuder, 1988). By testing the DP framework in middle distance running, the current study presented an opportunity to build on these empirical precursors and to ascertain a clearer conception of the acquisition of expert performance in the sport. In addition, recent DP research has suggested the possibility of a qualitatively different definition of DP unique to sport (Helsen et al., 1998; Hodges & Starkes, 1996 Young & Salmela, 1998a). In light of this, it is possible that environmental differences between music and sport could have some bearing on the validity of the DP framework within the athletic domain. Thus, the current study further tested the validity of the DP constructs in a sport-specific situation. Finally, middle distance running was an attractive research domain for two reasons: first, it has an objective, univariate measure of performance that does not require an extrinsic validation of expertise; second, its athletes are renowned for maintaining training logs that are highly descriptive records of practice and performance.

Previous studies relied on retrospective recall from memory and were inclined to overestimate amounts of practice (Ericsson et al., 1993; Hodges et al., 1996; Krampe, 1994). Since the data in the current investigation was predominantly derived from logs, it presumably represented a more accurate account of accumulated amounts of practice.

Recent research (Young & Salmela, 1998) collectively identified five activities as DP for middle distance running according to a modified conception of Ericsson et al's (1993) original construct. In the same study, investigators found no significant differences between national, provincial, and club level runners in terms of how they perceived elements of their practice. The present research intended to confirm whether this parity for perceptions also existed for athletes' actual participation in practice. Moreover, the main purpose of this study was to implement the most recent conception for DP (Young & Salmela, 1998a) in order to test the Ericsson framework for the acquisition of expert performance (Ericsson et al., 1993) in a sport-specific situation. Analyses compared accumulated amounts of practice between three competitive performance groups across the first nine years of their careers. More specifically, the three groups were contrasted for accumulated measures of DP for middle distance running. Further analyses traced the practice-performance relationship across their careers and identified key intervals for performance acquisition. Finally, regression analyses integrated components of practice and possible elements of "natural talent" in a predictive matrix for performance in middle distance running.

Method

Participants. Seventy-nine Canadian middle distance track athletes participated in the study. This same sample had been recruited for previous research by the investigators (Young & Salmela, 1998). Each participant voluntarily participated in the research following the administration of a letter of information and informed consent (Appendix B). Each participant was currently training for and competing in either the 800, 1500, or 3000 m events. The athletes were assigned to one of three performance groups based on their ultimate career-best personal performance record using the Athletics Canada Olympic Trials (1996) performance standards. The 3000 m performance criteria were extrapolations of the 800 and 1500 m standards using the Mercier Scoring Tables, a tool for normalizing track results across different running distances (Mercier & Beauregard, 1994). The *National* group was comprised of 31 athletes (19 males and 12 females) who had run faster than the Olympic Trials Provisional Qualifying Standard (Male: 800 m = 1:52.50; 1500 m = 3:48.00; 3000 m = 8:12.40; Female: 800 m = 2:09.00; 1500 m = 4:28.00; 3000 m = 9:35.10). More specifically, it consisted of 11, 15, and 5 athletes from the 800 m, 1500 m, and 3000 m events respectively. The *Provincial* group was comprised of 32 athletes (29 males and 3 females) who had achieved a performance time that was within 5% of the aforementioned criteria (Male: 800 m = 1:58.12; 1500 m = 3:59.40; 3000 m = 8:37.00; Female: 800 m = 2:15.45; 1500 m = 4:41.40; 3000 m = 10:03.80). The *Club* group consisted of 12, 13, and 7 athletes from the 800 m, 1500 m, and 3000 m events respectively. The *Club* group was comprised of 16 athletes (13 males and 3 females) who had run a performance time which was within 15% of the Olympic Trials qualifying standard (Male: 800 m = 2:09.37; 1500 m = 4:22.20; 3000 m = 9:26.26; Female: 800 m = 2:28.35; 1500 m = 5:08.20; 3000 m = 11:01.37). The *Club* group consisted of 4, 5, and 7 athletes respectively from the 800 m, 1500 m, and 3000 m events. The current ages of the three groups were as follows: National (*Nat*) = 25.45 ± 3.8 years (yrs); Provincial (*Prov*) = 21.64 ± 3.2 yrs; and *Club* = 20.2 ± 3.0 yrs.

Procedure. All participants received a three-part questionnaire. The first part of the questionnaire contained biographical information, e.g., current age, primary track event, whether or not the athlete was presently training and competing. The second part of the questionnaire asked the participants to consult their own training logs in order to recall quantitative aspects of their training across their career. Starting with the year at which the athlete initiated systematic practice with a coach, the athlete was instructed to recall information about a "typical" week of training 10 weeks prior to their peak race. Similarly, the athlete was asked to recall the same information for each two year interval from that point onward in their career. Specifically, the participants were asked to account for how much time (in minutes) they had engaged in each of the following 12 activities in a typical week: *Cross Training, Flexibility, Mental Preparation, Easy Run, Hard/Tempo Run, Long Interval Work/Fartlek, Short Interval/Speed Work, Race/Time Trial, Technique, Power Weights, Endurance Weights, Work with a Coach.* Furthermore, participants were instructed to account for typical weekly kilometers run in the following activities: *Easy Run, Hard/Tempo Run, Long Interval Work/Fartlek, Short Interval/Speed Work, Race/Time Trial.* The third part of the questionnaire required the participants to consult their training logs in order to recall the length of their off-season, in weeks, and their personal records of performance after their first year of systematic training and for each two year interval from that point onward in their career.

Reliability. The information obtained from the participants' questionnaire was considered to be both valid and reliable. All participants were asked to complete their questionnaire by consulting their personal training logs and records of performance. Across all three groups, 83.9% of the participants (*Nat* = 88.2%, *Prov* = 80.1%, *Club* = 80.6%) indicated that they had consulted their training logs in order to accurately complete their questionnaire.

Data conversions and statistical analyses. As in previous research (Ericsson et al., 1993; Hodges & Starkes, 1996), before performing the statistical analyses, it was necessary to convert data from the "typical" training week into accumulated amounts of practice at different intervals of their career. Beginning with the start of systematic track practice (start age) and for each two-year interval onward, average weekly amounts of practice were obtained. These weekly totals were subsequently multiplied by the number of training weeks per year (52 weeks minus the estimated length of the off-season) to obtain average annual totals for each two-year career interval. Annual totals were then multiplied by two to account for the two year interval total and then cumulatively summed to ascertain accumulated amounts of practice after start age, as well as after three, five, seven, and nine years of training.

For the comparison of starting ages of systematic practice between the performance groups, the data was analyzed using a simple ANOVA. In order to examine the monotonic relation and the power law of practice, the attained level of performance was graphed as a function of cumulative amounts of practice. Pearson correlations were performed after different career intervals in order to determine the developmental periods at which the performance-practice relationship was strongest.

For accumulated amounts of practice, two types of statistical analyses were carried out. After start age, three, five, and seven years of training, simple ANOVAs were used to compare cumulative amounts of practice between the *Nat*, *Prov*, and *Club* groups. The sources of any significant effects were identified through post-hoc Bonferroni tests. Table 1 shows the number of participants as well as their relative distribution with respect to performance group for each simple ANOVA analysis. After nine years of training, the attrition of participants in the *Club* group (N = 8) resulted in the removal of this group from subsequent analyses. Thus, after nine years, independent t-tests were used to compare differences in amounts of practice between only the *Nat* and *Prov* groups. All statistical tests were completed with alpha set at $\underline{p} < .05$.

Finally, a three-step hierarchical regression was used to explain within group variance for performance in Mercier points[1] (Mercier & Beauregard, 1994) after start year, three, five, seven, and nine years (yrs.) of systematic training. Performance group was entered first. In the second step, log values[2] of accumulated kilometers (kms.), accumulated minutes (mins.) of practice in all track activities, and accumulated mins. of DP, were each entered independently along with the performance group factor. This step was integral for determining whether there was any additional within group variance in performance beyond the performance group factor that could be explained by the practice variables. As the third step, the performance group was removed from the equation to

Table 1. Number of Participants by Performance Group for the Statistical Analyses of Accumulated Practice Data.

Career Interval	Nat Group	Prov Group	Club Group	Total
After Start Age	31	32	16	79
After Three Years	31	32	16	79
After Five Years	31	29	11	71
After Seven Years	29	24	11	64
After Nine Years	26	17	NA[a]	43

Note. All statistical procedures involved simple ANOVAs at each career interval. In some cases, participants failed to provide data for all career intervals and the number of participants is smaller. [a] The attrition of participants in the Club group negated the continued use of simple ANOVAs and independent t-tests were conducted for only the Nat and Prov groups.

determine the degree to which accumulated practice could singularly account for middle distance running performance. This step was integral for determining: a) which of the three practice variables alone explained the most within group variance in performance; and b) whether practice variables alone could explain as much within group variance in performance as the performance group factor.

Results

Between Performance Group Comparisons for Starting Ages of Systematic Practice

An analysis of the biographical data revealed similar trends of immersion into middle distance running for all three of the performance groups. First, there were no significant differences between the *Nat* (M = 12.95 ± 3.3 yrs.), *Prov* (M = 12.44 ± 3.2 yrs.), and *Club* (M = 11.47 ± 2.9 yrs.) groups for the age at which they began running,

$F(2, 76) = 1.093$, $p = .341$. Second, there were no significant differences between the *Nat* (M = 14.81 ± 2.7 yrs.), *Prov* (M = 14.30 ± 3.1 yrs.), and *Club* (M = 14.20 ± 2.3 yrs.) groups for the age at which they began systematic training with a coach, $F(2, 76) = .378$, $p = .686$. Finally, the *Nat* (M = 16.31 ± 2.8 yrs.), *Prov* (M = 15.76 ± 2.4 yrs.), and *Club* (M = 15.53 ± 2.4 yrs.) groups all reported similar ages for the commencement of full-time training, $F(2, 76) = .682$, $p = .509$.

The Practice-Performance Relationship and the Power Law of Practice

The relationships between attained level of performance in Mercier points (Mercier & Beauregard, 1994) and the accumulated practice variables obeyed the power law of practice (Anderson, 1982; Newell & Rosenbloom, 1981) for all three of the performance groups. All three practice variables: practice in all track activities (Figure 1), DP (Figure 2), and kilometers run (Figure 3), demonstrated an inverse function analogous to a typical skill acquisition or learning curve, in which performance gains were greatest at the onset of systematic training but less discernible later in their careers. Collapsed across all three of the performance groups, the relationship between level of performance and accumulated practice (Table 2) was strongest after three yrs. of training for practice in all track activities, $r(68) = .438$, $p < .01$, for DP, $r(70) = .270$, $p < .05$, and for kilometers run, $r(69) = .435$, $p < .01$. Later, particularly after nine yrs. of training, these relationships were less pronounced.

Table 2. Pearson Correlation Coefficients between Accumulated Practice and Acquired Level of Performance Collapsed across All Three Groups at Different Intervals of their Careers.

	Practice in All Track Activities	DP	Kilometers Run
After Start Age	r(64) = .226	r(66) = .255*	r(64) = .278*
After Three Yrs.	r(68) = .438**	r(70) = .270*	r(69) = .435**
After Five Yrs.	r(63) = .385**	r(65) = .261*	r(64) = .403**
After Seven Yrs.	r(55) = .271*	r(57) = .120	r(54) = .329*
After Nine Yrs.	r(45) = .242	r(46) = .186	r(42) = .276

Note. Numbers in brackets represent number of cases involved in the analyses.
* $p < .05$ ** $p < .01$

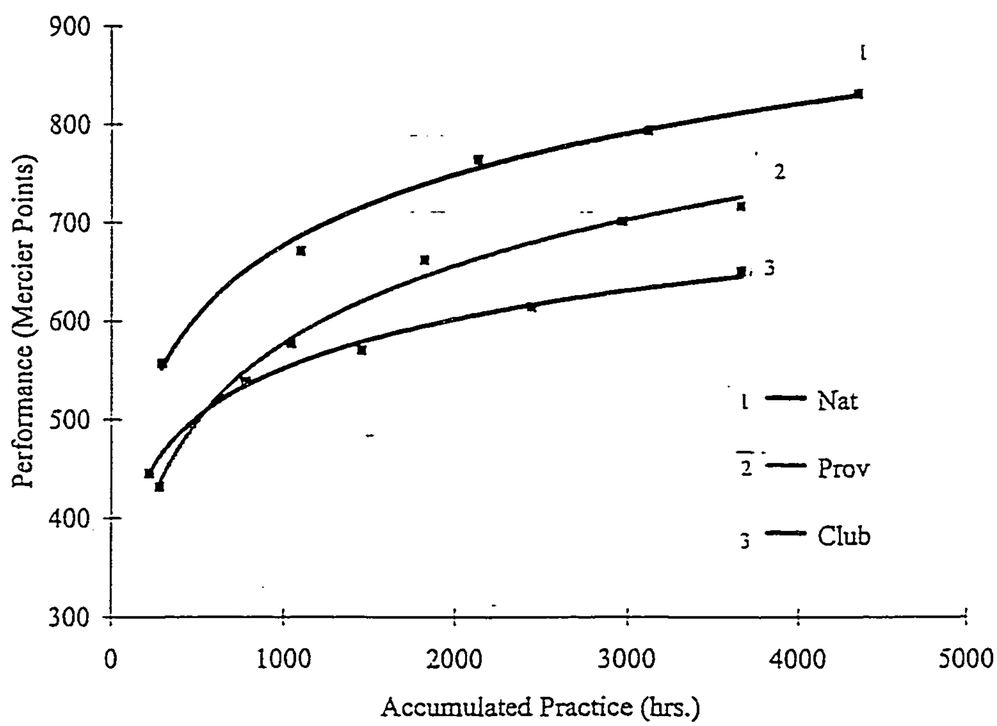

Figure 1. Relationship between accumulated amounts of practice in all track activities and performance collapsed across all three groups.

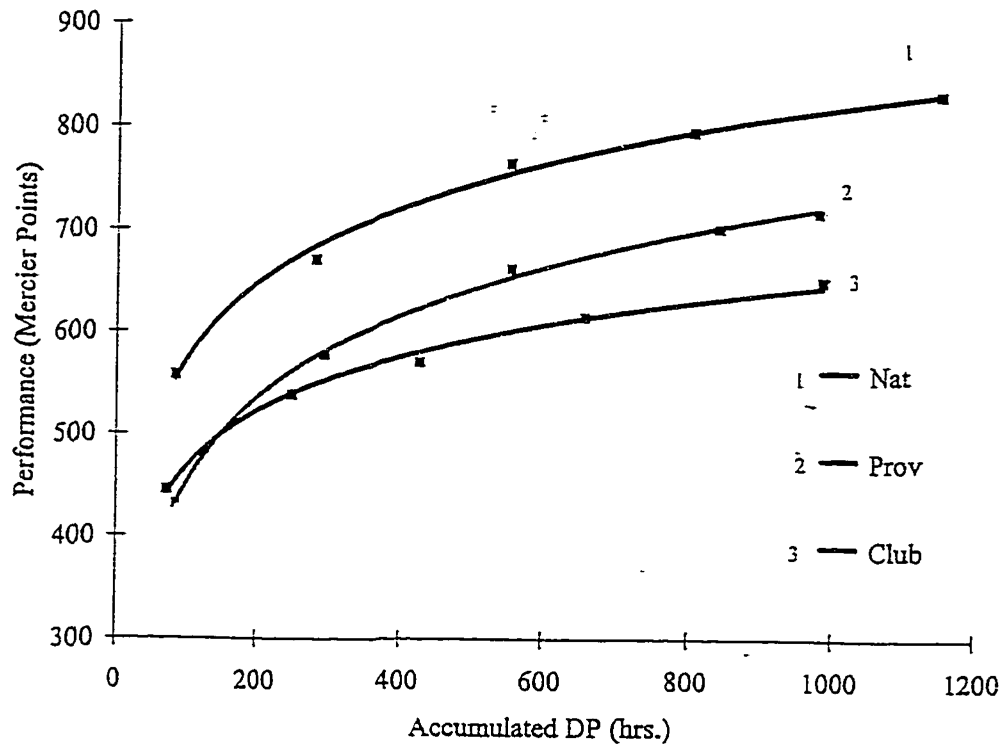

Figure 2. Relationship between accumulated amounts of deliberate practice and performance collapsed across all three groups.

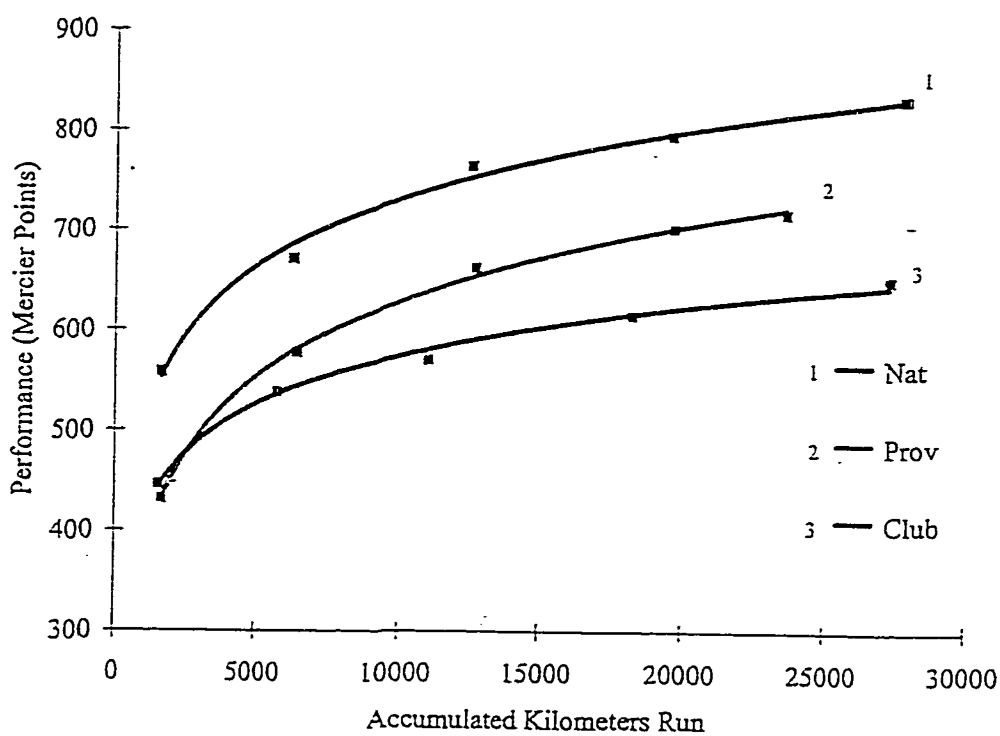

Figure 3. Relationship between accumulated kilometers run and performance collapsed across all three groups.

The Monotonic Relationship between Performance Groups over a Career for Accumulated Practice in All Track Activities, Accumulated DP, and Accumulated Kilometers Run

First, accumulated amounts of practice in all track activities were examined (Figure 4). Results failed to yield significant differences between the performance groups after start age, $F(2, 73) = 0.831$, $p = .440$, after three, $F(2, 70) = 1.286$, $p = .283$, five, $F(2, 62) = 1.701$, $p = .191$, seven, $F(2, 55) = 0.813$, $p = .449$, nor after nine yrs. of training, $t(35) = 1.05$, $p = .301$. However, there was a direct correspondence between performance groups and accumulated amounts of practice in all track activities: the *Nat* group had consistently engaged in more practice across their career than their lesser counterparts.

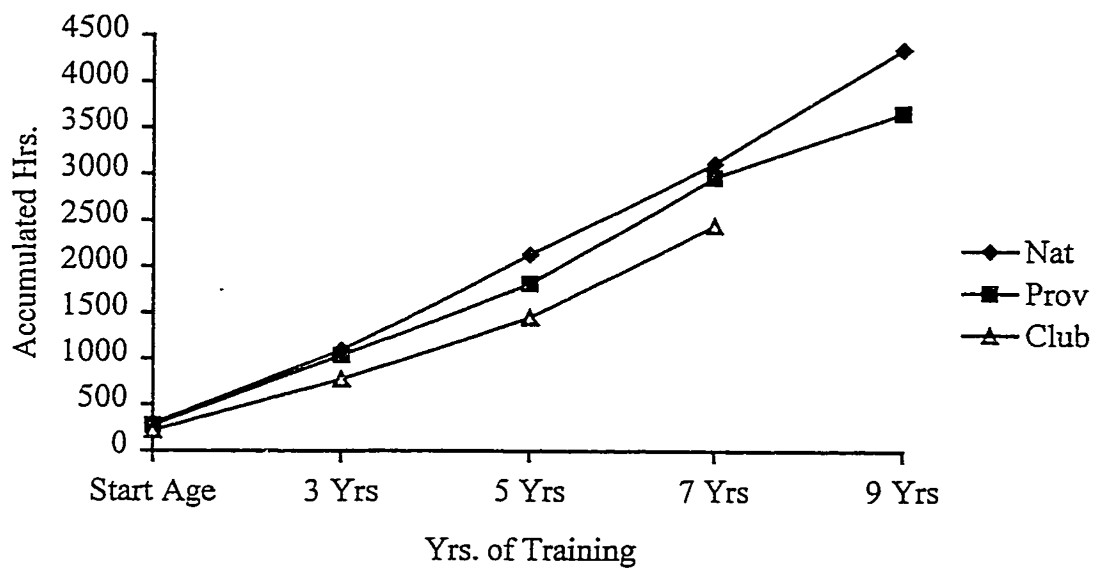

Figure 4. Accumulated amounts of practice for all track activities between performance groups over their careers.

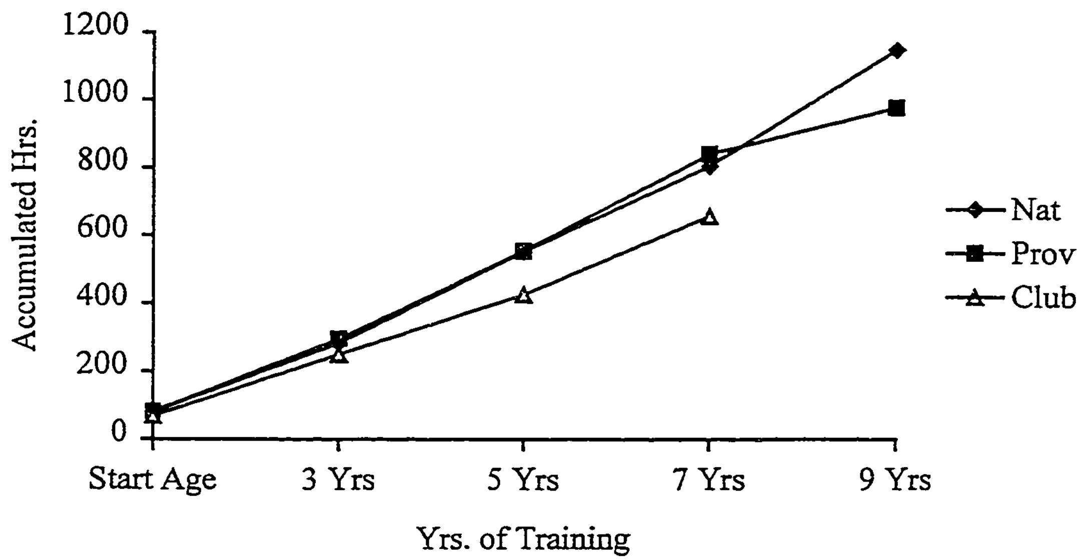

Figure 5. Accumulated amounts of deliberate practice between performance groups over their careers.

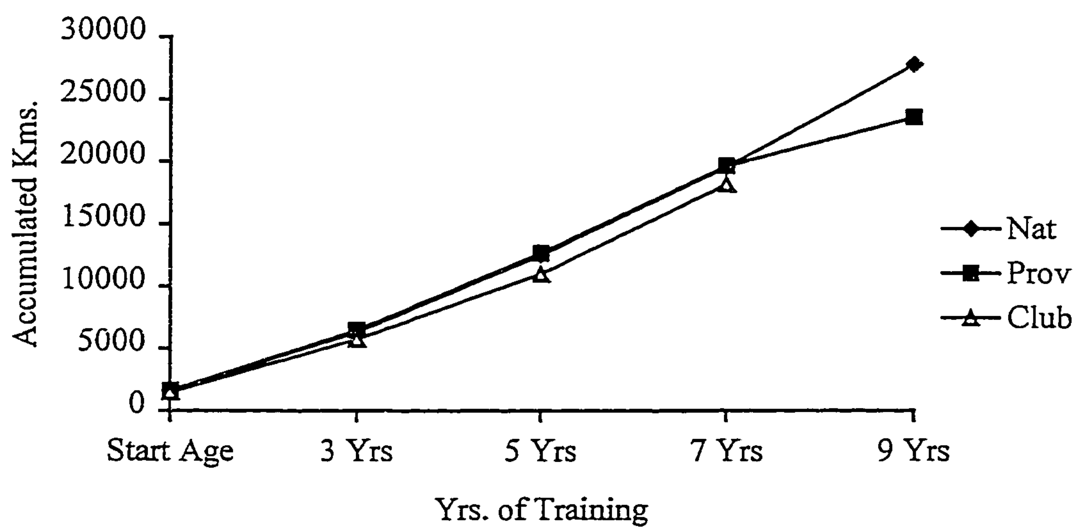

Figure 6. Accumulated kilometers run between performance groups over their careers.

Second, accumulated DP[3] was examined between performance groups over their careers (Figure 5). Again, there were no significant differences after start age, $F(2, 75) = 0.186$, $p = .831$, after three, $F(2, 72) = 0.256$, $p = .775$, five, $F(2, 64) = 0.681$, $p = .510$, nor after seven yrs. of systematic training $F(2, 57) = 0.584$, $p = .561$. After nine yrs. of training, the *Nat* group had accumulated more DP than the *Prov* group, however, this difference was not significant, $t(37) = .84$, $p = .407$.

Next, accumulated kilometers run were examined between performance groups over their careers (Figure 6). Again, there were no significant differences after start age, $F(2, 72) = 0.084$, $p = .920$, after three years, $F(2, 70) = 0.237$, $p = .789$, after five years, $F(2, 62) = 0.350$, $p = .706$, nor after seven years of training, $F(2, 53) = 0.155$, $p = .857$. Although these values did not reach a level of statistical significance, the *Nat* group had accumulated more running distance than the *Prov* group after nine years of training, $t(33) = 1.25$, $p = .221$.

Between Performance Group Comparisons over a Career for Accumulated Practice and Accumulated Kilometers Run in Individual Training Activities

Next, the 12 activities comprising the microstructure of practice were investigated; analyses examined each of the constituent activities for accumulated amounts of practice with the intention of identifying activities that could differentiate between the performance groups. Tables 3, 4, 5, and 6, present the ANOVA results for accumulated practice in each of the training activities after start age, three, five, and seven yrs. of training, respectively. Table 7 shows the t-test results between the *Nat* and *Prov* groups after nine yrs. of training. No statistically significant differences were found with the exception of one analysis. For *Work with a Coach*, there were significant differences between performance groups for accumulated amounts of practice after three years of training, F = 7.332, p = .001. Post-hoc Bonferroni tests indicated that both the *Nat* (M = 209.5 hrs) and *Prov* (M = 139.3 hrs) groups had engaged in significantly more *Work with a Coach* after three years than the *Club* group (M = 22.4 hrs). In fact, *Work with a Coach* distinguished between performance groups across the initial nine years of their careers (Figure 7)[4].

Tables 8, 9, 10, 11, and 12, present the results for between group differences in accumulated kilometers run for the individual training activities after start age, three, five, seven, and nine yrs. of training, respectively. No significant differences were discovered.

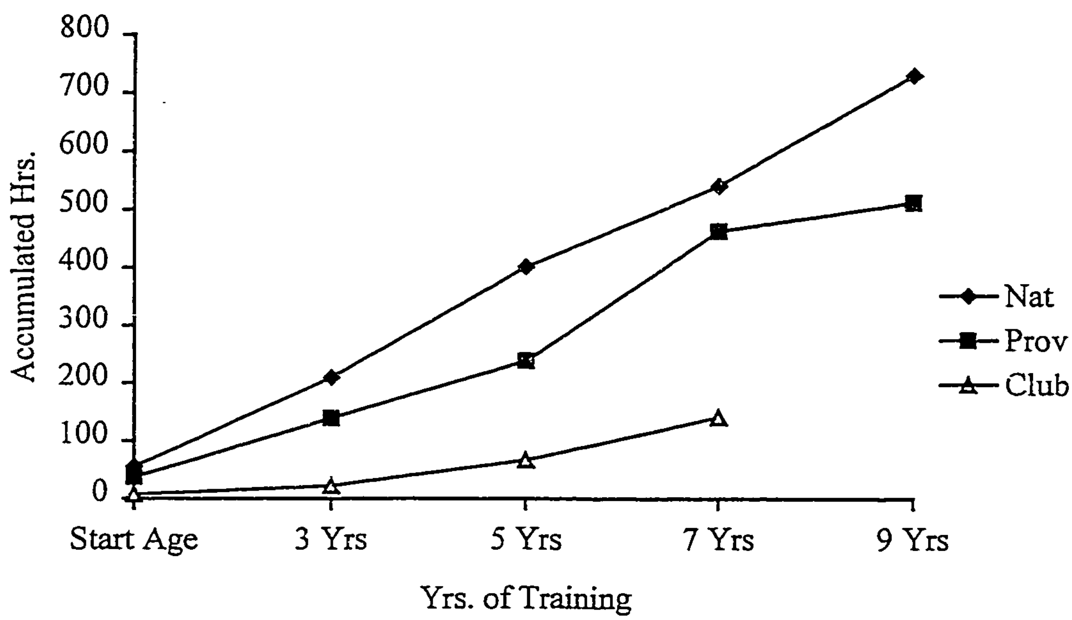

Figure 7. Accumulated amounts of practice for work with a coach between performance groups over their careers.

Table 3. One-way ANOVA Results for Differences in Accumulated Practice between National, Provincial, and Club Groups after Start Year.

	National (mins.)	Provincial (mins.)	Club (mins.)	df	F-ratio	p
Speed	1 676	1 719	1 575	2, 77	0.018	0.982
LIW	1 174	1 194	1 139	2, 77	0.009	0.992
H/TR	853	960	1 003	2, 78	0.100	0.905
MP	641	445	236	2, 77	1.286[a]	0.282[a]
Race	388	447	212	2, 75	2.114	0.128
DP	4 844	4 900	4 167	2, 75	0.186	0.831
Easy	3 741	3 731	3 913	2, 77	0.021	0.979
WwC	3 330	2 239	443	2, 75	2.386[a]	0.099[a]
Flex	2 013	1 743	1 834	2, 77	0.204	0.816
CT	1 201	2 653	1 396	2, 78	1.840[a]	0.166[a]
Tech	849	717	381	2, 78	1.064	0.350
EW	798	310	518	2, 78	1.354[a]	0.264[a]
PW	484	247	114	2, 78	0.516	0.600
Total	17 657	16 804	13 283	2, 73	0.831	0.440

Note. *Speed* (Short Interval Workout/ Speed Work); *LIW* (Long Interval Work/Fartlek); *H/TR* (Hard/Tempo Run); MP (Mental Preparation); *Race* (Race or Time Trial); *DP* (Deliberate Practice); Easy (Easy Run); *WwC* (Work with a Coach); *Flex* (Flexibility); *EW* (Endurance Weights); *CT* (Cross Training); *Tech* (Technique); *PW* (Power Weights).
[a] To conform with the statistical prerequisites of the ANOVA, these analyses were based on log transformations of the raw measures using a LN(x + 1) function whenever the equal variances assumption was violated.

Table 4. One-way ANOVA Results for Differences in Accumulated Practice between National, Provincial, and Club Groups after Three Years of Training.

	National (mins.)	Provincial (mins.)	Club (mins.)	df	F-ratio	p
Speed	5 502	5 102	5 112	2, 74	0.034	0.966
LIW	4 222	4 469	3 921	2, 74	0.082	0.921
H/TR	3 201	3 777	4 166	2, 75	0.321	0.726
MP	2 522	2 492	1 409	2, 75	0.744	0.479
Race	1 219	1 612	1 134	2, 73	1.044	0.357
DP	16 975	17 733	14 989	2, 72	0.256	0.774
Easy	15 238	15 145	13 985	2, 75	0.084	0.920
WwC	12 573	8 357	1 346	2, 72	7.332[a]	0.001*[a]
Flex	6 628	6 622	7 193	2, 75	0.054	0.948
CT	4 117	7 825	5 573	2, 76	1.093	0.340
EW	3 482	1 818	2 766	2, 76	0.504[a]	0.606[a]
Tech	2 779	2 714	1 376	2, 76	1.233	0.297
PW	2 014	1 249	676	2, 76	0.466	0.629
Total	65 595	62 305	46 495	2, 72	1.286	0.283

Note. [a] To conform with the statistical prerequisites of the ANOVA, these analyses were based on log transformations of the raw measures using a LN(x + 1) function whenever the equal variances assumption was violated.
* $p < .05$

Table 5. One-way ANOVA Results for Differences in Accumulated Practice between National, Provincial, and Club Groups after Five Years of Training.

	National (mins.)	Provincial (mins.)	Club (mins.)	df	F-ratio	p
Speed	10 308	8 482	5 456	2, 67	1.058	0.353
LIW	7 592	8 053	5 724	2, 66	0.611	0.546
H/TR	6 408	7 738	9 790	2, 67	0.893	0.414
MP	5 330	5 407	2 598	2, 67	1.070	0.349
Race	2 254	3 146	1 984	2, 64	0.014[a]	0.986[a]
DP	33 153	33 247	25 552	2, 64	0.681	0.510
Easy	31 512	28 096	25 325	2, 67	0.600	0.552
WwC	24 083	14 304	4 012	2, 64	3.546[b]	0.035[b]
Flex	13 167	10 193	11 083	2, 66	0.729	0.486
EW	7 916	3 427	4 104	2, 68	1.456[a]	0.240[a]
CT	7 105	12 548	11 870	2, 68	1.263[a]	0.289[a]
Tech	6 622	4 452	2 573	2, 68	1.730	0.185
PW	3 807	2 072	1 505	2, 68	0.470	0.627
Total	127 826	108 854	86 823	2, 62	1.701	0.191

Note. [a] To conform with the statistical prerequisites of the ANOVA, these analyses were based on log transformations of the raw measures using a LN(x + 1) function whenever the equal variances assumption was violated. [b] These analyses were based on measures which violated the equal variances assumption even after log transformation.

Table 6. One-way ANOVA Results for Differences in Accumulated Practice between National, Provincial, and Club Groups after Seven Years of Training.

	National (mins.)	Provincial (mins.)	Club (mins.)	df	F-ratio	p
Speed	14 501	12 661	7 876	2, 60	0.913	0.407
H/TR	10 475	10 166	14 509	2, 60	0.751	0.476
LIW	10 048	11 787	8 773	2, 59	0.633	0.534
MP	8 216	10 108	4 845	2, 60	0.972	0.384
Race	3 252	5 150	3 442	2, 57	0.297[a]	0.745[a]
DP	48 299	50 458	39 446	2, 57	0.584	0.561
Easy	48 700	46 191	42 834	2, 60	0.202	0.818
WwC	32 490	27 822	8 494	2, 58	2.001[a]	0.144[a]
Flex	19 490	15 374	20 154	2, 59	0.736	0.483
EW	10 805	6 373	7 596	2, 59	0.115[a]	0.892[a]
Tech	9 748	7 596	4 533	2, 61	1.135	0.328
CT	9 592	18 627	18 717	2, 61	1.985[a]	0.146[a]
PW	7 786	2 986	4 211	2, 61	1.090	0.343
Total	186 824	177 922	146 693	2, 55	0.813	0.449

Note. [a] To conform with the statistical prerequisites of the ANOVA, these analyses were based on log transformations of the raw measures using a LN(x + 1) function whenever the equal variances assumption was violated.

Table 7. Independent *t*-test Results for Differences in Accumulated Practice between National and Provincial Groups after Nine Years of Training.

	National (mins.)	Provincial (mins.)	df	t-value	p
Speed	19 807	15 789	40	0.62	0.538
LIW	15 481	15 973	39	- 0.12	0.901
H/TR	14 992	12 613	40	0.59	0.556
MP	11 653	8 221	36.79	1.38	0.175
Race	4 595	6 037	22.72	- 0.88	0.389
DP	69 005	58 725	37	0.84	0.407
Easy	67 921	61 320	40	0.61	0.544
WwC	43 922	30 817	38	0.80	0.427
Flex	26 998	17 883	39	1.52	0.137
EW	15 302	10 195	39	1.34	0.189
CT	14 396	27 615	22.48	- 1.54	0.138
Tech	12 084	9 071	40	0.73	0.468
PW	10 527	2 891	27.93	1.68	0.103
Total	261 075	219 658	35	1.05	0.301

Table 8. One-way ANOVA Results for Differences in Accumulated Kilometers Run between National, Provincial, and Club Groups after Start Year.

	National (kms.)	Provincial (kms.)	Club (kms.)	df	F-ratio	p
Easy	899	805	842	2, 75	0.121	0.886
LIW	194	208	185	2, 75	0.130	0.879
H/TR	174	246	243	2, 77	0.605	0.549
Speed	174	192	177	2, 74	0.089	0.915
Race	79	125	55	2, 73	2.251	0.113
Total Run	1 596	1 622	1 502	2, 72	0.084	0.920

Note. Easy (Easy Run); *H/TR* (Hard/Tempo Run); *LIW* (Long Interval Work/Fartlek); *Speed* (Short Interval Workout/ Speed Work); *Race* (Race or Time Trial); *Total Run* (Total Kilometers in Running Activities).

Table 9. One-way ANOVA Results for Differences in Accumulated Kilometers Run between National, Provincial, and Club Groups after Three Years of Training.

	National (kms.)	Provincial (kms.)	Club (kms.)	df	F-ratio	p
Easy	3 719	3 302	3 168	2, 73	0.300	0.742
LIW	755	863	657	2, 72	0.652	0.524
H/TR	665	980	1 021	2, 74	1.097	0.339
Speed	612	734	607	2, 72	0.530	0.591
Race	277	468	311	2, 71	0.700[a]	0.500[a]
Total Run	6 338	6 483	5 764	2, 70	0.237	0.789

Note. [a] To conform with the statistical prerequisites of the ANOVA, these analyses were based on log transformations of the raw measures using a LN(x + 1) function whenever the equal variances assumption was violated.

Table 10. One-way ANOVA Results for Differences in Accumulated Kilometers Run between National, Provincial, and Club Groups after Five Years of Training.

	National (kms.)	Provincial (kms.)	Club (kms.)	df	F-ratio	p
Easy	7 320	6 196	5 590	2, 65	0.866	0.426
H/TR	1 455	2 012	2 454	2, 66	1.453	0.241
LIW	1 442	1 905	1 228	2, 64	1.615	0.207
Speed	1 184	1 476	1 206	2, 64	0.762	0.471
Race	527	874	525	2, 62	0.028[a]	0.973[a]
Total Run	12 528	12 677	11 003	2, 62	0.350	0.706

Note. [a] To conform with the statistical prerequisites of the ANOVA, these analyses were based on log transformations of the raw measures using a LN(x + 1) function whenever the equal variances assumption was violated.

Table 11. One-way ANOVA Results for Differences in Accumulated Kilometers Run between National, Provincial, and Club Groups after Seven Years of Training.

	National (kms.)	Provincial (kms.)	Club (kms.)	df	F-ratio	p
Easy	11 289	10 495	9 748	2, 58	0.242	0.786
H/TR	2 477	2 788	3 684	2, 59	0.794	0.457
LIW	2 180	2 763	2 034	2, 56	0.893	0.415
Speed	1 828	2 234	1 802	2, 57	0.628	0.537
Race	766	1 462	943	2, 54	0.528[a]	0.593[a]
Total Run	19 597	19 678	18 211	2, 53	0.155	0.857

Note. [a] To conform with the statistical prerequisites of the ANOVA, these analyses were based on log transformations of the raw measures using a LN(x + 1) function whenever the equal variances assumption was violated.

Table 12. Independent *t*-test Results for Differences in Accumulated Kilometers Run between National and Provincial Groups after Nine Years of Training.

	National (kms.)	Provincial (kms.)	df	t-value	p
Easy	15 769	13 842	38	0.72	0.473
H/TR	3 686	3 355	39	0.30	0.769
LIW	3 358	3 465	36	- 0.12	0.904
Speed	2 470	2 520	37	- 0.09	0.928
Race	1 105	1 597	21.20	- 1.15	0.262
Total Run	27 827	23 610	33	1.25	0.221

Hierarchical Regression Models: Explaining within Group Variance in Middle Distance Running Performance over a Career

Tables 13-17 display the amounts of explained variance (R^2) in running performance after the successive implementation of the three regression models at each career interval. The tables illustrate a number of findings. First, the performance group factor alone explained middle distance running performance across their entire career spans; all R^2s in the first step were significant ($p < .05$). However, this was expected, particularly later in their careers, since the performance group was ultimately based on career-best performances that typically occurred later in their careers. Second, the accumulated practice variables explained additional within group variance in running performance beyond the performance group factor. Kilometers run contributed significantly to R^2 values from start age ($\alpha = .44$, $R^2 + .18$) up to nine yrs. of training ($\alpha =$

.19, $R^2 + .08$). Practice in all track activities, and DP, explained additional variance beyond the performance group factor for the initial five yrs. ($\alpha = .33$, $R^2 + .11$), and the initial three yrs. ($\alpha = .35$, $R^2 + .14$), respectively. Third, all three accumulated practice variables alone explained a significant amount of variance in performance up to five yrs.; all R^2s in the third step were significant up to five yrs. of training (Table 15). Inspection of the beta weights revealed that the relation was in the predicted direction: those participants who had practiced more achieved higher performance scores. Kilometers run was the accumulated practice variable that explained the most variance in the regression equation: kilometers run alone demonstrated a significant R^2 after seven yrs. of systematic training ($\alpha = .28$, $R^2 = .08$).

A comparison of R^2s between the first and the third steps in the hierarchy revealed an interesting finding. After start age (Table 13) and after three yrs. of training (Table 14), kilometers run and practice in all track activities both singularly explained more variance in middle distance running performance than the performance group factor alone. Thus, even when performance group was controlled for statistically, those athletes who had run more kilometers and spent more time in all forms of track practice achieved higher performance scores. DP alone explained more variance in performance than the performance group factor only after start age (Table 13).

Table 13. Hierarchical Regression for Middle Distance Running Performance as Accounted for by Performance Group and Accumulated Practice Variables after Start Year.

Predictor Variables	Beta	R^2	R^2 Change
Step 1: Performance Group	0.286*	.08*	+.08
Step 2A:		.26*	+.18
Performance Group	0.267*		
Kilometers Run	0.436*		
Step 2B:		.24*	+.16
Performance Group	0.272*		
DP	0.401*		
Step 2C:		.23*	+.15
Performance Group	0.248*		
Practice in All Track Activities	0.395*		
Step 3A: Kilometers Run	0.436*	.19*	-.07
Step 3B: Practice in All Track Activities	0.407*	.17*	-.07
Step 3C: DP	0.402*	.16*	-.07

* denotes significant variables in the regression equation and significant variance at $p < .05$

Table 14. Hierarchical Regression for Middle Distance Running Performance as Accounted for by Performance Group and Accumulated Practice Variables after Three Years of Training.

Predictor Variables	Beta	R^2	R^2 Change
Step 1: Performance Group	0.411*	.17*	+.17
Step 2A:		.51*	+.34
Performance Group	0.418*		
Kilometers Run	0.579*		
Step 2B:		.43*	+.26
Performance Group	0.388*		
Practice in All Track Activities	0.491*		
Step 2C:		.31*	+.14
Performance Group	0.448*		
DP	0.353*		
Step 3A: Kilometers Run	0.577*	.33*	-.18
Step 3B: Practice in All Track Activities	0.526*	.28*	-.15
Step 3C: DP	0.338*	.11*	-.20

* denotes significant variables in the regression equation and significant variance at $p < .05$

Table 15. Hierarchical Regression for Middle Distance Running Performance as Accounted for by Performance Group and Accumulated Practice Variables after Five Years of Training.

Predictor Variables	Beta	R^2	R^2 Change
Step 1: Performance Group	0.662*	.44*	+.44
Step 2A:		.66*	+.22
Performance Group	0.653*		
Kilometers Run	0.458*		
Step 2B:		.55*	+.11
Performance Group	0.621*		
Practice in All Track Activities	0.332*		
Step 2C:		.52*	+.08
Performance Group	0.663*		
DP	0.275		
Step 3A: Kilometers Run	0.479*	.23*	-.43
Step 3B: Practice in All Track Activities	0.415*	.17*	-.38
Step 3C: DP	0.286*	.08*	-.44

* denotes significant variables in the regression equation and significant variance at $p < .05$

Table 16. Hierarchical Regression for Middle Distance Running Performance as Accounted for by Performance Group and Accumulated Practice Variables after Seven Years of Training.

Predictor Variables	Beta	R^2	R^2 Change
Step 1: Performance Group	0.740*	.55*	+.55
Step 2A:		.66*	+.11
Performance Group	0.765*		
Kilometers Run	0.307*		
Step 2B:		.61*	+.06
Performance Group	0.735*		
Practice in All Track Activities	0.238*		
Step 2C:		.58*	+.03
Performance Group	0.746*		
DP	0.160		
Step 3A: Kilometers Run	0.280*	.08*	-.58
Step 3B: Practice in All Track Activities	0.265	.07	-.54
Step 3C: DP	0.142	.02	-.56

* denotes significant variables in the regression equation and significant variance at $p < .05$

Table 17. Hierarchical Regression for Middle Distance Running Performance as Accounted for by Performance Group and Accumulated Practice Variables after Nine Years of Training.

Predictor Variables	Beta	R^2	R^2 Change
Step 1: Performance Group	0.822*	.68*	+.68
Step 2A:		.76*	+.08
Performance Group	0.844*		
Kilometers Run	0.191*		
Step 2B:		.74*	+.06
Performance Group	0.834*		
Practice in All Track Activities	0.130		
Step 2C:		.73*	+.05
Performance Group	0.848*		
DP	0.089		
Step 3A: Kilometers Run	0.231	.05	-.69
Step 3B: Practice in All Track Activities	0.234	.05	-.69
Step 3C: DP	0.130	.02	-.71

* denotes significant variables in the regression equation and significant variance at $p < .05$

Discussion

The present findings strengthen confidence in the bare-boned, underlying assumptions that provided the impetus for such work. In several respects, however, the present findings also challenge some of the theoretical tenets recently advanced within the DP framework for the acquisition of exceptional performance (Ericsson et al., 1993). The question impressed upon researchers in the field is whether practice does make expert? In this particular investigation, the question was whether differences in accumulated amounts of practice explained ultimate levels of performance for Canadian middle distance runners? Moreover, did Ericsson et al.'s (1993) monotonic relationship between accumulated practice and acquired level of performance prove true, and, if so, did the acquisition curve obey the inverse power law of practice?

The array of statistical analyses confirmed that the monotonic relationship between accumulated practice and attained performance level has held true. The monotonic function essentially indicated that increased amounts of practice led to an improvement in running performance, rather than performance improving in spite of little practice. Furthermore, the monotonic relation conformed to the power law of practice, thereby corroborating typical skill acquisition curves (Anderson, 1982; Newell & Rosenbloom, 1981) and the functional tenet outlined by Ericsson et al. (1993). The relationship between accumulated practice and resultant performance was most powerful during the initial three years of training, after which the relationship gradually became less robust.

There were two purposes for the retrospective analyses of accumulated practice: to discover whether there existed between group differences for accumulated practice; and to identify key intervals over a career where these differences were particularly evident. Tests for accumulated DP failed to reveal significant differences between the performance groups at any of the career intervals. Similarly, there were no significant group differences for accumulated amounts of all track practice, nor were there any significant differences for accumulated kilometers run.

Results demonstrated complete correspondence between ultimate performance group and accumulated practice after nine years of training. In the case of DP, practice in all track activities, and kilometers run, the national-calibre group exhibited higher totals than their provincial level counterparts after nine years. For accumulated amounts of DP, the national and provincial groups reversed trends just after seven years of training: the national group began to accumulate more DP, with the gap widening markedly after nine years. Similar patterns were displayed for accumulated amounts of practice in all track activities and kilometers run. Helsen et al. (1998) studied the training patterns of soccer and field hockey players and, based on accumulated practice trends, they identified nine years into a career as a watershed period for the acquisition of expert performance in these sports. Beyond nine years, there were significant contrasts between performance groups for amounts of practice. The results from the present study hinted that the same critical period exists for middle distance running, and that the significant differences between national, provincial, and club level athletes may lie on the other side of the nine year mark.

The lone mean difference between performance groups occurred for accumulated work with a coach after three years of training. Both the national-level runners (M = 210 hours) and the provincial group (M = 139 hours) had accumulated significantly more work with a coach than the club-level runners (M = 22 hours). Perhaps the most encompassing, but least defined dimension of Ericsson et al.'s (1993) framework was the role of the teacher or coach (Salmela, 1996b). These findings support an argument for the entrenchment of supervised instruction into the sport-specific definition of DP. Prior to the start of systematic training, intra-individual and, perhaps, group differences in performance reflect the athlete's ability to adapt adequate performance enhancing strategies in the absence of a coach. Furthermore, expert performers have been shown to exhibit less reliance on a coach and increased control over their own development late in their careers (Bloom, 1985). However, the results from the present study point to the formative role of a coach early in a runner's career, i.e., from start age to three years. Work with a coach differentiated between performance groups during a period when, according to the acquisition curve (Table 2) and regression results (Table 14), performance gains were greatest and practice variables dictated the most variance in individual performance.

The role of the running coach is to enable their affiliated athlete to overcome each of the three constraints to the acquisition of expert performance - the resource, effort, and motivational constraints (Ericsson et al., 1993). A good coach is a resource of knowledge and training material, and can effectively streamline the process of skill acquisition by imparting sound strategies for performance enhancement. By directing their personal resources to the organisation of practice, the coach sets the direction of DP and, in doing so, resolves the effort and motivational constraints (Salmela, 1996b). The coach coordinates aspects of organisation, training, and competition in order to balance maximal bouts of effort with sufficient recovery (Côté, Salmela, Trudel, Baria, & Russell, 1995). Finally, coaches provide external motivation and encouragement within the training environment (Salmela, 1996a). By interacting with a coach, the developing athlete benefits from an optimal training environment and increases the efficiency of skill acquisition. The results from this study appeared to reflect these coach-athlete interactions, particularly early in a runner's career.

Previous research has suggested that over a decade of systematic preparation and the accumulation of more than 10,000 hours of DP were necessary, but not sufficient prerequisites for the acquisition of expert level performance (Chase & Simon, 1973; Ericsson et al., 1993). Due to the attrition of participants after nine years of training, the present analyses unfortunately could not test the 10-year rule. However, the present study did provide an accurate examination of accumulated practice. National and provincial level runners had accumulated an average of 4,351 and 3,661 hours of total track practice, respectively, after nine years of training. When the same analysis was confined for DP, both the national-level athletes (M = 1,150 hours) and the provincial-calibre runners (M = 979 hours) were well below the predicted 10,000 hours.

There are several plausible explanations to account for the lower than expected accumulated amounts of practice. First, the fact that this study failed to examine top level international athletes, or what could be considered to be an authentic expert sample of middle distance runners, may have resulted in less than dramatic accumulated totals of practice. Second, the original work by Ericsson et al. (1993) may have resulted in over-estimations of the actual amounts of practice. The initial study with violinists failed to report reduced practice during the off-season. In addition, the retrospective recall methodology was vulnerable to practitioners' bias; participants recalled amounts of practice they had aspired to do rather than what they actually had accumulated (Ericsson et al., 1993; Helsen et al., 1998; Hodges & Starkes, 1996). Third, results from the most recent work examining the DP framework has indicated that the prerequisite accumulated totals for achieving high-level status in sport may, in fact, be well less than in other domains (Helsen et al., 1998).

In order to illustrate this last point, it is necessary to compare the accumulated practice of the national level runners with similar performance groups from other fields. After nine years of training, best estimates derived from line graphs of accumulated practice indicated that Ericsson et al.'s (1993) "good violinists" had compiled approximately 6,500 hours of training - substantially more than the Canadian national runners (M = 4,351 hours). In fact, the good violinists had accumulated comparatively more practice than Helsen et al.'s (1998) national-level soccer and field hockey players. After nine years, the soccer players had achieved around 3,500 hours of accumulated practice and the hockey players had accumulated just over 4,000 hours. A more recent study exhibited the astronomically large amounts of accumulated practice required for expert performance in music (Krampe & Ericsson, 1996). Older expert pianists had accumulated in excess of 55,000 hours of practice over a 15 year period of formal training. Despite the fact that these numbers were obtained from an authentic expert sample over an additional six years of training, it seems easy to presume that these numbers would dwarf similar accumulations within the sporting domain. Van Rossum (in press) also concluded that the generalised notion of 10,000 hours of DP was an over-estimation; recent studies of the training careers of Dutch international field hockey players indicated such and prompted van Rossum to seriously question its validity for sport.

The Canadian national runners' totals seem to corroborate results from other sports and suggest that the prerequisite accumulated practice totals for achieving high level status in sport may be less than for the arts or music. Indeed, if the acquisition of high-level performance in sport is governed by lower accumulated amounts of practice, the question is why? One answer may relate to performers' perceptions of effort and concentration required to practice in their domain. On a 10 point scale, expert instrumental musicians rated the perceived effort to perform 12 music-related activities on average to be 6.33 (Ericsson et al., 1993). On a similar scale, Canadian runners judged the perceived physical effort to perform 12 track practice activities on average to be 6.69 and the perceived concentration to perform these same activities to be 7.06 (Young & Salmela, 1998). According to the effort constraint postulated by Ericsson and colleagues, activities that are perceived to be highly effortful by the performer will necessarily be limited in duration. As is the case in middle distance running, if the preponderance of training is of an effortful nature, then presumably the accumulated practice totals should be lower, thereby reflecting the effort constraint imposed by the nature of the practice.

However, since the other investigated sports failed to consistently show an inverse relationship between, on one hand, perceived effort (wrestlers M = 6.36, soccer players M = 5.51, field hockey players M = 5.19) and concentration (wrestlers M = 5.46, soccer players M = 5.43, field hockey players M = 5.92), and accumulated practice, this argument may likely only apply to sports in which relevant practice has markedly low work to rest ratios, such as middle distance running or competitive weight-lifting.

Although the final set of analyses did not test Ericsson et al.'s (1993) conceptual axioms in the strictest sense, the regression models were purposively implemented to answer the following question: did differences in accumulated amounts of DP account for significant variance in performance as compared to other variables? The hierarchical regression analyses for each career interval determined: a) whether accumulated practice explained additional within group variance in performance that the ultimate performance group factor could not capture (Step 2); b) whether accumulated practice alone significantly explained variance in middle distance running performance (Step 3). Each of the three accumulated practice variables, kilometers run, practice in all track activities, and DP, were independently and successively implemented in the three step regression models. The accumulated practice variables explained additional within group variance in middle distance running performance beyond the ultimate performance group factor. Kilometers run contributed significantly to R^2 values from start age up to nine years into their careers. To a lesser extent, practice in all track activities accounted for additional variance in performance up to seven years into their careers. DP explained additional variance beyond the ultimate performance group factor for only the initial three years of training.

By controlling for the ultimate performance group factor, the present analyses permitted the comparisons of the predictability of each of the accumulated practice variables alone. Of the three, kilometers run was clearly the most robust predictor in the regression models; kilometers run alone accounted for significant variance in performance after start age through to after seven years of training. Practice in all track activities alone, as well as DP alone, explained significant variance in performance after start age through after five years of training. Most importantly, both kilometers run alone and practice in all track activities alone accounted for substantially more within group variance in performance after three years than the ultimate performance group factor (Step 3 compared to Step 1). These findings support previous work in which researchers discovered that accumulated musical practice alone could account for differences in piano performance, just as well as the a skill group factor (Ericsson et al., 1993).

These findings also challenge the commonly held notion that "natural talent" is somehow responsible for exceptional performance (Anderson, 1995; Klavora, Georgevski, Forsyth, Higgins, Divaston, & Little, 1998; Montville, 1997; Prokop, 1975; Salmela, 1996b). It is still maintained by many in running circles that natural talent, or a stable, hereditary gift, is the precursor to running greatness. According to this perspective, elite athletes are blessed with more natural talent than their lesser-skilled peers and this talent precludes the need for maximal amounts of practice. In effect, natural talent is perceived as a stronger predictor of running performance than practice; the most elite runners can achieve comparatively better performances on less training. The natural talent argument is more commonly invoked to explain high levels of performance early in a runner's career, i.e., early adolescent performance, and has become the underlying principle for talent identification systems (Klavora, Georgevski, Forsyth, Higgins, Divaston, & Little, 1998; Petiot, Salmela, & Hoshizaki, 1987; Régnier, Salmela, & Russell, 1993; Russell, 1989; Salmela, 1996b; Salmela & Régnier, 1983).

This study provided the opportunity to test the predictive value of a natural talent construct for running performance. The natural talent construct was logically deduced according to the following axioms: first, according to the natural talent perspective, performance is primarily moderated by each athlete's amount of inborn talent; second, the performance group factor in this study was a valid categorisation for ultimate running performance; and third, by deduction, the ultimate performance group factor in this study should have corresponded to amounts of natural talent. Simply, the national group should presumably have been blessed with more natural talent than their provincial level and club level peers. In sum, the ultimate performance group factor in this study was an operable construct for testing the predictive value of natural talent using hierarchical regressions.

Since the ultimate performance group was based on career-best performances that typically occurred later in their career span, e.g., after nine years of training, the performance group factor, as expected, primarily accounted for performance later in their careers. According to the natural talent perspective, however, the performance group should also have explained more within group variance in performance than any of the accumulated practice variables early in their careers. The results pointed to the contrary hypothesis. After three years of training, kilometers run and practice in all track activities predicted far more variance in performance than their ultimate performance level, or the natural talent factor. What is the importance of this finding? At the very age targeted by talent identification and selection programs, practice variables most demonstrably explained middle distance running performance. Talent identification schemes strategically remove athletes from the developmental pool during a period when the relationship between practice and performance is the strongest.

Limitations and Future Research

The scope of this study was limited in that it only traced nine years of systematic training. In light of the nine year watershed proposed by Helsen et al. (1998) and the "10-year rule" (Simon & Chase, 1973), this investigation did not fully satisfy the requirements for a study on the acquisition of expertise. Future research should trace the practice-performance relationship beyond 10 years of systematic training.

Like previous research, the conversion of weekly amounts of practice to annual amounts was based on an assumption of stability, i.e., weekly amounts deviated very little across the training year (Ericsson et al., 1993; Helsen et al., 1998; Hodges & Starkes, 1996). In reality, however, the athletic training principles that dictate running fitness demand dramatic changes in training volume throughout an annual cycle (Coe & Martin, 1991; Freeman, 1989; Lydiard & Gilmour, 1978; Sleamaker, 1989). In the current study, data was collected for a typical week that was 10 weeks prior to the peak race of the season. It was strategically positioned at a mid-point when athletes are completing their aerobic capacity and anaerobic threshold training and are beginning to engage more speed and speed endurance training (Coe & Martin, 1991). This period was chosen because it best reflected a wide mélange of training activities used to develop different energy systems for middle distance running. The trade-off is that annual estimates based on this period neglected higher volumes of training undertaken earlier in the season. This limitation may have partially accounted for the lower than predicted amounts of accumulated practice discussed previously. Future research may wish to examine runners' practice patterns across an entire year, however, this would be a very ambitious task. A more practical resolution may be to implement an assumption that reflects the oscillating volumes of training across the annual cycle, e.g., sinuous curve, when converting weekly totals to annual estimates of practice.

There were several inherent weaknesses that the present methodological framework shared with previous research in the field (Ericsson et al., 1993; Helsen et al., 1998; Hodges & Starkes, 1996; Krampe, 1994; Krampe & Ericsson, 1996). Although the DP framework recognises the importance of motivational factors, research has yet to account for their role in the acquisition of expert performance. Second, there is no measure that accurately controls for the quality or intensity of practice when researchers are examining accumulated amounts of practice. Currently, research appears to be based on an assumption of equivalent intensity across, as well as within, performance groups.

Finally, there is the question of how to quantify skills or physiological benefits transferred between similar domains, for example from cross-country skiing to biathlon, or attributes indirectly acquired through casual practice or "deliberate play" (Côté & Hay, in press) prior to systematic practice. The present study failed to establish baseline measures for performance at 0 hours of accumulated practice. The initial values on the performance acquisition curves (Figures 1-3) plotted after the first year of systematic training indicated significant differences between the national and provincial groups, $F = 4.59$, $p = .016$. Since this performance discrepancy was noted after a year of systematic training during which the national and provincial groups participated in different amounts of training, there was difficulty in interpreting the results. The performance values plotted on the graphs (Figures 1-3) after the initial year of systematic practice reflected varying amounts of accumulated practice. Without adequate baseline measures for acquired performance level at 0 hours of practice, the investigators were subjected to the unwieldy task of teasing out the components: did the initial performance values genuinely reflect differences in accumulated practice after the first year of training?; or did these initial performance values also reflect the inadvertent acquisition of performance prior to the start of systematic practice? Considering that the participants began running for fun on average two years before they started systematic training, it is possible that the latter scenario was partially true. Undoubtedly, a degree of indirect performance acquisition would have occurred, thereby predisposing individuals to heightened levels of performance early in their careers. To further complicate matters, these between group differences exhibited after one year of systematic training could very well be construed as "natural talent", i.e., inborn attributes that manifest themselves and account for between group differences in performance despite training. Future research should implement methodological designs that account for baseline measures of performance prior to the start of systematic practice. Future research exploring the acquisition of expertise should make efforts to address these contentious issues. However, these admitted limitations should not override the empirical and methodological advances inherent in the present study, nor should they detract from the present study's novel findings for the acquisition of exceptional performance.

Empirical and Methodological Advances

In the present study, it is noteworthy that DP was identified a priori to the analyses. The five training activities that collectively defined DP had already been identified in previous research based on the same runners' perceptions of their running practice (Young & Salmela, 1998) and in accordance with a modified conception of Ericsson et al.'s (1993) rating scales. Previous works that examined DP performed their statistical analyses on total amounts of practice for all training activities (Ericsson et al., 1993; Helsen, Starkes, & Hodges, 1998; Hodges & Starkes, 1996; Krampe & Ericsson, 1996). No consideration was granted to the perceived relevance, effort, and enjoyment, attached by participants to the constituent activities. Only in post hoc analyses did researchers identify the domain-specific, constituent activities of DP. Thus, conclusions were not based on a strictly defined construct of DP, but rather on a more encompassing definition of practice. In this investigation, in order to confidently determine whether the current sport-modified construct of DP was a prime mediator for the acquisition of expert performance, DP was first identified a priori, then analysed distinctly from total amounts of practice over all training activities.

Some criticism has been directed at the reliability of the retrospective recall process from memory (Davids, in press; van Rossum, in press). Despite reports that have emphasised the reliability of the self-report data (Starkes, in press), the previous sport studies exhibited over-estimations ranging from 18-35 % in average weekly hours practised. The present study represented a methodological advance for research within the DP framework. The participants' recall of accumulated practice data was stimulated by artifactual records kept in their personal training logs across their careers. These highly detailed training logs were assumed to be quite accurate and interpretable even after a long time interval. Therefore, unlike previous research (Ericsson et al., 1993; Helsen et al., 1998; Hodges & Starkes, 1996), burdensome diary studies were not required to check the reliability of recall, nor was the data susceptible to large inflation biases.

Conclusion

In summary, the findings reaffirmed some of the theoretical tenets that govern the DP framework for the acquisition of exceptional performance. There was complete correspondence between amounts of accumulated practice and performance group after nine years of training. Practice variables explained within-group variance in performance after seven years into a career, but alone were the primary mediators of performance for the initial three years of a career. The monotonic relationship between practice and attained level of performance and the fact that it proceeds in accordance with the power law of practice was once again confirmed. Furthermore, supplementary regression analyses demonstrated that a natural talent construct appeared to be an invalid predictor of running performance, certainly early in a career. The pressing question - whether practice does make expert, cannot be concretely answered in this study. It is fair to conclude that practice early in a career is a far better predictor of middle distance running performance than the ultimate performance group factor. Future research beyond the nine-year threshold is required to reveal potentially significant group differences for accumulated practice.

In several respects, the findings raised more questions regarding the DP framework for the acquisition of expertise. Except for working with a coach, significant mean differences between performance groups for accumulated practice were not particularly evident up to nine years of training. With regard to support for a theoretical framework for the development of sport expertise based solely on DP, the answer is still unclear. The current sport-modified construct of DP was upstaged as the primary mediator of high-level middle distance running performance - both kilometers run and practice in all track activities served as better predictors of performance. This result reinforces expressed concerns regarding the exact definition of DP in sport (Young & Salmela, 1998).

References

Anderson, J.R. (1982). Acquisition of cognitive skill. Psychological Review, 89, 369-406.

Athletics Canada. (1996). Olympic trials qualifying standards. Ottawa: Athletics Canada.

Bloom, B.S. (1985). Developing talent in young people. New York: Ballantine.

Charness, N., Krampe, R.Th., Mayr, U. (1996). The role of practice and coaching in entrepreneurial skill domains: An international comparison of life-span chess skill acquisition. In K.A. Ericsson (Ed.), The road to excellence: The acquisition of expert performers in the arts and sciences, sports and games (pp.51-80). Mahwah, NJ: LEA.

Coe, P., & Martin, D. (1991). Training distance runners: The art and science of optimal training. Champaign, IL: Leisure Press.

Côté, J., & Hay, J. (in press). Family influences on youth sport performance and participation. In J.M. Silver & D. Stevens (Eds.), Psychological foundations of sport (2nd edition).

Côté, J., Salmela, J.H., Trudel, P., Baria, A., & Russell, S.J. (1995). The coaching model: A grounded assessment of expert gymnastic coaches' knowledge. Journal of Sport and Exercise Psychology, 17, 1-17.

Davids, K. (in press). Skill acquisition and the theory of deliberate practice: It ain't what you do it's the way that you do it! International Journal of Sport Psychology.

Doherty, J.K. (1964). Modern training for running. Englewood Cliffs, NJ: Prentice-Hall.

Ericsson, K.A. (1996). The acquisition of expert performance: An introduction to some of the issues. In K.A. Ericsson (Ed.), The road to excellence: The acquisition of expert performance in the arts and sciences, sports and games (pp.1-50). Mahwah, NJ: LEA.

Ericsson, K.A., Krampe, R.Th., & Tesch-Ršmer, C. (1993). The role of deliberate practice in the acquisition of expert performance. Psychological Review, 100, 3, 363-406.

Freeman, W.H. (1989). Peak when it counts. Los Altos, CA: Tafnews Press.

Glover, B., & Schuder, P. (1988). The new competitive runner's handbook. New York: Penguin.

Gustin, W.C. (1985). The development of exceptional research mathematicians. In B.S. Bloom (Ed.), Developing talent in young people (pp.270-331). New York: Ballantine Books.

Hagan, R.D., Smith, M.G., & Gettman, L.R. (1981). Marathon performance in relation to maximal aerobic power and training indices. Medicine and Science in Sports Exercise, 13, 185-189.

Helsen, W. F., Starkes, J.L., & Hodges, N.J. (1998). Team sports and the theory of deliberate practice. Journal of Sport and Exercise Psychology, 20, 12-34.

Hodges, N. J., & Starkes, J.L. (1996). Wrestling with the nature of expertise: A sport specific test of Ericsson, Krampe and Tesch-Ršmer's theory of "deliberate practice". International Journal of Sport Psychology, 27, 400-424.

Klavora, P., Georgevski, R., Forsyth, A., Higgins, A., Dovaston, S., & Little, E. (1998). Checking out the talent. Athletics, Feb./March, 8-12.

Krampe, R.Th. (1994). Maintaining excellence: Cognitive-motor performance in pianists differing in age and skill level. Berlin: Max-Planck-Institut für Bildungsforschung.

Krampe, R.Th., & Ericsson, K.A. (1996). Maintaining excellence: Deliberate practice and elite performance in young and older pianists. Journal of Experimental Psychology: General, 125, 4, 331-359.

Lydiard, A., & Gilmour, G. (1978). Running the Lydiard way. Mountain View, CA: World Publications.

Mercier, D. & Beauregard, S. (1994). Mercier scoring tables. Ottawa: Athletics Canada.

Montville, L. (1997). 100th best. Sports Illustrated, July 28, 68-80.

Newell, A., & Rosenbloom, P.S. (1981). Mechanisms of skill acquisition and the law of practice. In J.R. Anderson (Ed.), Cognitive skills and their acquisition, (pp. 1-55). Hillsdale, NY: LEA.

Noakes, T. (1991). Lore of running: Discover the science and spirit of running. Champaign, IL: Leisure Press.

Partington, J.T. (1995). Making music. Ottawa: Carleton University Press.

Patel, V.L., Kaufman, D.R., & Magder, S.A. (1996). The acquisition of medical expertise in complex dynamic environments. In K.A. Ericsson (Ed.), The road to excellence: The acquisition of expert performance in the arts and sciences, sports and games (pp.127-165). Mahwah, NJ: LEA.

Petiot, B., Salmela, J.H., & Hoshizaki, T.B. (1987). World identification systems for gymnastic talent. Montreal: Sport Psyche.

Prokop, D. (1975). In the end, the individual is the key. In D. Prokop (Ed.), The African running revolution (pp.70-75). Mountain View, CA: World Publications.

Régnier, G., Salmela, J.H., & Russell, S.J. (1993). Talent detection and development in sport. In R.N. Singer, M. Murphey, & L.K. Tennant (Eds.), Handbook of research on sport psychology (pp. 290-313). New York: Macmillan.

Russell, K. (1989). Athletic talent: From detection to perfection. Science Periodical on Research and Technology in Sport, 9, Jan.

Sack, H.-G. (1975). Sports activity and personality. Ahrensburg: Verlag Ingrid Czwalina.

Sack, H.-G. (1980). The psychology of elite adolescent athletes. A longitudinal study of male and female long-distance runners over a period of four years towards the end of adolescence. Schondorf: Hofmann.

Salmela, J.H. (1996a). Great job coach! Getting the edge from proven winners. Ottawa: Potentium.

Salmela, J.H. (1996b). Expert coaches' strategies for the development of expert athletes. In V.A. Rogozkin & R. Maughan (Eds.), Current research in sport sciences: An international perspective (pp. 2-19). New York: Plenum Press.

Salmela, J.H., & Régnier, G. (1983). A model for sport talent identification. Science Periodical on Research and Technology in Sport, Oct.

Simon, H.A. & Chase, W.G. (1973). Skill in chess. American Scientist, 61, 394-403.

Sleamaker, D. (1989). Serious training for serious athletes. Dubuque, IA: Kendall/Hunt.

Sloboda, J.A. (1996). The acquisition of musical performance expertise: Deconstructing the "talent" account of individual differences in musical expressivity. In K.A. Ericsson (Ed.), The road to excellence: The acquisition of expert performance in the arts and sciences, sports and games (pp.107-126). Mahwah, NJ: LEA.

Sosniak, L.A. (1985). Learning to be a concert pianist. In B.S. Bloom (Ed.), Developing talent in young people (pp.19-67). New York: Ballantine.

Starkes, J.L. (in press). The road to expertise: Is practice the only determinant? International Journal of Sport Psychology.

Starkes, J.L., Deakin, J.M., Allard, F., Hodges, N.J., & Hayes, A. (1996). Deliberate practice in sport: What is it anyways? In K.A. Ericsson (Ed.), The road to excellence: The acquisition of expert performance in the arts and sciences, sports and games (pp.81-106). Mahwah, New Jersey: LEA.

van Rossum, J.H.A. (in press). Deliberate practice and Dutch field hockey: An addendum to Starkes (1998). International Journal of Sport Psychology.

Wallingford, R. (1975). Long distance running. In A.W. Taylor (Ed.), The scientific aspects of sports training (pp.118-130). Springfield, IL: Charles C Thomas.

Young, B.W., & Salmela, J.H. (1998). Deliberate practice according to middle distance runnners' perceptions of training. Unpublished master's thesis, University of Ottawa.

Endnotes

[1] Mercier Points refer to normalized numeric values used to compare different performances across a variety of track distances (Mercier & Beauregard, 1994). As such, they were a reliable tool for comparing performances across the 800, 1500, and 3000 m track events.

[2] The accumulated amounts were log-transformed prior to analysis in accordance with the theoretical premise of the power law of practice (Anderson, 1982; Newell & Rosenbloom, 1981).

[3] DP for middle distance running was an amalgamation of five activities: Hard Runs or Tempo Runs, Long Interval Workouts, Short Interval or Speed Work, Races or Time Trials, and Mental Preparation (Young & Salmela, 1998)

[4] Figures for all the other individual training activities that failed to demonstrate significant differences between performance groups are displayed in Appendix D.

CONCLUSION

What makes an expert? Perhaps it is presumptuous to proclaim that a scientific framework, whether it be a genetic or an environmental model, can capture all the ingredients of expertise. It is more practical to examine whether exceptional performers share common traits or experiences that differentiate them from their lessers. Ericsson, Krampe, and Tesch-Römer (1993) conceived a conceptual framework for doing exactly this, when they boldly postulated that practice was the primary mediator of expertise, then subsequently introduced a conceptual skeleton for its study and application. In the scientific tradition, the current project tested this relatively new framework for the acquisition of exceptional performance. In doing so, the present findings consolidated previously advanced tenets, contradicted others, and derived novel trends which, if convincingly replicated in future research, may be assimilated into the framework.

Does practice make expert? Is practice the variable that foremost determines the acquisition of expertise? These pressing questions have not yet been unequivocally resolved by scientific endeavors, nor admittedly so, can they be answered in this study. However, there are several trends that can be surmised from this research in middle distance running. First, the most elite runners consistently engaged in more accumulated practice than their lesser counterparts; there was complete correspondence between amounts of accumulated practice and performance group after nine years of training. In the future, research beyond nine years of systematic training is required to elucidate potentially significant group differences for accumulated practice. Second, accumulated practice variables accounted for significant variance in performance after seven years of training, but, more importantly, they were the primary mediators of running performance for the initial three years of a career. In fact, practice early in a career was a far better predictor of middle distance running performance than the eventual performance group factor.

The current research reaffirmed some of the theoretical tenets and underlying assumptions that govern the DP framework for the acquisition of exceptional performance (Ericsson et al., 1993). First, the monotonic relationship between practice and attained level of performance and the fact that it proceeds in accordance with the power law of practice was once again confirmed. Clearly, the graphs for the performance acquisition curves bore striking resemblance to typical motor learning curves. Furthermore, as a supplement to the DP framework, the present study advanced an argument to debunk the notion of natural talent; a natural talent construct appeared to be an invalid predictor of running performance, particularly early in a career. However, the reliability of future research along these lines will necessarily be contingent upon the establishment of baseline measures for performance prior to the start of systematic practice.

The current findings also evoked some expressed concerns regarding the DP construct in sport. Contrary to the original construct proposed by Ericsson et al. (1993), Certain DP activities were perceived by the middle distance runners to be relatively enjoyable. This finding in particular challenged the generalizability of the DP definition and suggested that concessions must be recognized for its application in sport. Otherwise, DP was perceived by runners as activities that were highly relevant for improving performance, and that required either great amounts of physical effort or high levels of concentration. Significant mean differences between performance groups for working with a coach emphasized the role of an instructor or mentor in the sport-specific definition of DP. With regard to a theory of sport expertise based solely on DP, the answer is still unclear. The sport-modified construct of DP was upstaged as the primary mediator of high-level running performance - both kilometers run and practice in all track activities were better predictors of performance.

Scholars and lay people have interminably searched for the recipes for excellence, yet, the acquisition of expertise, as a veritable empirical field of study, is in its infancy. Admittedly, the conceptual framework advanced within this field has yet to demonstrate the true empirical resolve characteristic of a scientific theory. The analytical and methodological approaches adopted in the study of expertise lack a robustness; they are modifiable, vulnerable to criticism, and, ideally, welcoming to suggestions. Apart from extensive longitudinal or cross-sectional schemes, future research will most certainly expand upon the retrospective methodology. The current research offered two important advances to this process that should be considered for future research within the field. First, the retrospective recall of accumulated amounts of practice was stimulated by descriptive, artifactual records in the athletes' training logs. When participants were attempting to reconstruct their practice environment nine years previous, a recall methodology based on training diaries was assumingly more accurate than employing recall from memory. Future studies should incorporate supporting analyses of reliability to ensure confidence in the training logs as an effective tool for recall. Second, although no significant mean differences between the performance groups were found with the exception of working with a coach, the current research conducted analyses to differentiate between constituent activities within the microstructure of practice. Future research in the field of expertise acquisition should not only examine total amounts of practice or DP, but also the changing emphases within the underlying microstructure of practice.

REFERENCES FOR REVIEW OF LITERATURE

Anderson, J.R. (1982). Acquisition of cognitive skill. Psychological Review, 89, 369-406.

Anderson, O. (1995). What research tells us about African runners: Are they really genetically more gifted? Peak Performance, Nov., 63, 7-10.

Andersen, P., & Henriksson, J. (1977). Training induced changes in the subgroups of human type II skeletal muscle fibres. Acta Physiologica Scandinavia, 99, 123-125.

Bloom, B.S. (1985). Developing talent in young people. New York: Ballantine.

Bouchard, C., & Lortie, G. (1984). Heredity and endurance training. Sports Medicine, 1, 38-64.

Bouchard, C., & Malina, R.M. (1984). Genetics and Olympic athletes: A discussion of methods and issues. In J.E.L. Carter (Ed.), Kinanthropometry of Olympic athletes (pp.28-38). Basel, Switzerland: Karger.

Boulay, M.R., Lortie, G., Simoneau, J-A., & Bouchard, C. (1986) Sensitivity of maximal aerobic power and capacity to anaerobic training is partly genotype dependent. In R.M. Malina & C. Bouchard (Eds.), Sport and human genetics (pp.173-182). Champaign, IL: Human Kinetics.

Charness, N., Krampe, R.Th., Mayr, U. (1996). The role of practice and coaching in entrepreneurial skill domains: An international comparison of life-span chess skill acquisition. In K.A. Ericsson (Ed.), The road to excellence: The acquisition of expert performers in the arts and sciences, sports and games (pp.51-80). Mahwah, NJ: LEA.

Doherty, J.K. (1964). Modern training for running. Englewood Cliffs, NJ: Prentice-Hall.

acquisition. In K.A. Ericsson (Ed.), The road to excellence: The acquisition of expert performers in the arts and sciences. sports and games (pp.51-80). Mahwah, NJ: LEA.

Doherty, J.K. (1964). Modern training for running. Englewood Cliffs, NJ: Prentice-Hall.

Elovaino, R., & Sundberg, S. (1983). A five-year follow-up study on cardio-respiratory function in adolescent elite endurance runners. Acta Paediatrica Scandinavia, 72, 351-356.

Ericsson, K.A. (1990). Peak performance and age: An examination of peak performance in sports. In Baltes & Baltes (Eds.), Successful aging: Perspectives of the behavioral sciences (pp.164-196). New York: Cambridge University Press.

Ericsson, K.A. (1996). The acquisition of expert performance: An introduction to some of the issues. In K.A. Ericsson (Ed.), The road to excellence: The acquisition of expert performance in the arts and sciences. sports and games (pp.1-50). Mahwah, NJ: LEA, Inc.

Ericsson, K.A., Krampe, R.Th., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. Psychological Review, 100, 3, 363-406.

Fox, E.L., & Matthews, D.K. (1981). The physiological basis of physical education and athletics (3rd edition). Philadelphia: Saunders.

Galton, F. Sir (1979). Hereditary genius: An inquiry into its laws and consequences. London: Julian Friedman Publishers. (Originally published in 1869).

Glover, B., & Schuder, P. (1988). The new competitive runner's handbook. New York: Penguin.

Hagan, R.D., Smith, M.G., & Gettman, L.R. (1981). Marathon performance in relation to maximal aerobic power and training indices. Medicine and Science in Sports Exercise, 13, 185-189.

Helsen, W. F., Starkes, J.L., & Hodges, N.J. (1998). Team sports and the theory of deliberate practice. Journal of Sport and Exercise Psychology, 20, 12-34.

Hodges, N. J., & Starkes, J.L. (1996). Wrestling with the nature of expertise: A sport specific test of Ericsson, Krampe and Tesch-Römer's theory of "deliberate practice". International Journal of Sport Psychology, 27, 400-424.

Howald, H. (1976). Ultrastructure and biochemical function of skeletal muscle in twins. Annals of Human Biology, 3, 455-462.

Howald, H. (1982). Training-induced morphological and functional changes in skeletal muscle. International Journal of Sports Medicine, 3, 1-12.

Howe, M.J.A. (1990). Introduction. In M.J.A. Howe (Ed.), Encouraging the development of exceptional skills and talents (pp.1-16). Leicester: The British Psychological Society.

Jansson, E., Sjodin, B., & Tesch, P. (1977). Changes in muscle fibre type distribution in man after physical training. Acta Physiologica Scandinavia, 104, 315-324.

Jolesz, F., & Sreter, F.A. (1981). Development, innervation, and activity-pattern induced changes in skeletal muscle. Annual Review of Physiology, 43, 531-552.

Kalinowski, A.G. (1985). The development of Olympic swimmers. In B.S. Bloom (Ed.), Developing talent in young people (pp.139-192). New York: Ballantine.

Klavora, P., Georgevski, R., Forsyth, A., Higgins, A., Dovaston, S., & Little, E. (1998). Checking out the talent. Athletics, Feb./March, 8-12.

Komi, P.V., Viitasalo, J.H.T., Havu, M., Thorstensson, A., Sjodin, B., & Karlsson, J. (1977). Skeletal muscle fibres and muscle enzyme activities in monozygous and dizygous twins of both sexes. Acta Physiologica Scandinavia, 100, 385-392.

Krampe, R.Th. (1994). Maintaining excellence: Cognitive-motor performance in pianists differing in age and skill level. Berlin: Max-Planck-Institut fur Bildungsforschung.

Krampe, R.Th., & Ericsson, K.A. (1996). Maintaining excellence: Deliberate practice and elite performance in young and older pianists. Journal of Experimental Psychology: General, 125, 4, 331-359.

Liquori, M., & Parker, J.L. (1980). Real running. USA: Wideview Books.

Malina, R.M. (1986). Genetics of motor development and performance. In R.M. Malina & C. Bouchard (Eds.), Sport and human genetics (pp.23-58). Champaign, IL: Human Kinetics.

Malina, R.M. & Bouchard, C. (1986). Concluding remarks. In R.M. Malina and C. Bouchard (Eds.), Sport and human genetics: The 1984 Olympic scientific congress proceedings (pp.183-186). Champaign, IL: Human Kinetics.

Manners, J. (1975). African recruiting boom. In D. Prokop (Ed.), The African running revolution (pp.62-69). Mountain View, CA: World Publications.

Monsaas, J.A. (1985). Learning to be a world-class tennis player. In B.S. Bloom (Ed.), Developing talent in young people (pp.211-269). New York: Ballantine.

Monster, A.W., Chan, H.C., & O'Connor, D. (1978). Activity patterns of human skeletal muscles: Relation to muscle fibre type composition. Science, 200, 314-317.

Montville, L. (1997). 100th best. Sports Illustrated, July 28, 68-80.

Newell, A., & Rosenbloom, P.S. (1981). Mechanisms of skill acquisition and the law of practice. In J.R. Anderson (Ed.), Cognitive skills and their acquisition, (pp. 1-55). Hillsdale, NY: LEA.

Noakes, T. (1991). Lore of running: Discover the science and spirit of running. Champaign, IL: Leisure Press.

Partington, J.T. (1995). Making music. Ottawa: Carleton University Press.

Patel, V.L., Kaufman, D.R., & Magder, S.A. (1996). The acquisition of medical expertise in complex dynamic environments. In K.A. Ericsson (Ed.), The road to excellence: The acquisition of expert performance in the arts and sciences, sports and games (pp.127-165). Mahwah, New Jersey: LEA.

Petiot, B., Salmela, J.H., & Hoshizaki, T.B. (1987). World identification systems for gymnastic talent. Montreal: Sport Psyche.

Prokop, D. (1975). In the end, the individual is the key. In D. Prokop (Ed.), The African running revolution (pp.70-75). Mountain View, CA: World Publications.

Régnier, G., Salmela, J.H., & Russell, S.J. (1993). Talent detection and development in sport. In R.N. Singer, M. Murphey, & L.K. Tennant (Eds.), Handbook of research on sport psychology (pp. 290-313). New York: Macmillan.

Russell, K. (1989). Athletic talent: From detection to perfection. Science Periodical on Research and Technology in Sport, 9, Jan.

Sack, H.-G. (1975). Sportliche betatigung und personlichkeit. (Sports activity and personality). Ahrensburg: Verlag Ingrid Czwalina.

Sack, H.-G. (1980). Zur psychologie des jugenlichen leistungssports. Eine exemplarische langsschnitt-untersuchung an mannlichen und weiblichen langstreckenlaufern uber zeitraum von vier jahren am ende der adoleszenz. (The psychology of elite adolescent athletes. A longitudinal study of male and female long-distance runners over a period of four years towards the end of adolescence). Schondorf: Hofmann.

Salmela, J.H. (1996). Great job coach! Getting the edge from proven winners. Ottawa: Potentium.

Salmela, J.H., & Régnier, G. (1983). A model for sport talent identification. Science Periodical on Research and Technology in Sport, Oct.

Saltin, B., Larsen, H., Terrados, N., Bangsbo, J., Kim, C.K., Svedenhag, J., & Rolf, C.J. (1995). Aerobic exercise capacity at sea level and at altitude in Kenyan boys, junior, and senior runners compared with Scandinavian runners. Scandinavian Journal of Medicine and Science in Sports, 5 (4), Aug., 209-221.

Schantz, P., Billeter, R., Henriksson, J., & Jansson, E. (1982). Training-induced increase in myofibrillar ATPase intermediate fibres in human skeletal muscle. Muscle Nerve, 5, 628-636.

Simon, H.A. & Chase, W.G. (1973). Skill in chess. American Scientist, 61, 394-403.

Sloboda, J.A. (1996). The acquisition of musical performance expertise: Deconstructing the "talent" account of individual differences in musical expressivity. In K.A. Ericsson (Ed.), The road to excellence: The acquisition of expert performance in the arts and sciences, sports and games (pp.107-126). Mahwah, NJ: LEA.

Sosniak, L.A. (1985). Learning to be a concert pianist. In B.S. Bloom (Ed.), Developing talent in young people (pp.19-67). New York: Ballantine.

Starkes, J.L., Deakin, J.M., Allard, F., Hodges, N.J., & Hayes, A. (1996). Deliberate practice in sport: What is it anyways? In K.A. Ericsson (Ed.), The road to excellence: The acquisition of expert performance in the arts and sciences, sports and games (pp.81-106). Mahwah, NJ: LEA.

Tesch, P.A., & Karlsson, J. (1985). Muscle fibre types and size in trained and untrained muscles of elite athletes. Journal of Applied Physiology, 59, 5-6.

Wallingford, R. (1975). Long distance running. In A.W. Taylor (Ed.), The scientific aspects of sports training (pp.118-130). Springfield, IL: Charles C Thomas.

CONTRIBUTION OF COLLABORATORS

In the role of academic advisor, Dr. John Salmela encouraged me to initiate research in this field of study and provided feedback with regard to the methodologies, discussions of results, and conclusions in each of the two articles. Dr. Salmela was also instrumental in providing the final revisions for the current document.

APPENDIX A

Letter of Approval

LETTER OF APPROVAL

Dear Representative,

This study is part of a research project that is examining the causes of expert performance in sport. The University of Ottawa, in conjunction with Sport Canada and the Coaching Association of Canada, is studying talent development in high level competitive sport. We are now extending our efforts into the domain of middle distance track.

The process of talent development in sport remains an elusive phenomenon. The purpose of this research is to examine the relationship between both qualitative and quantitative aspects of practice and skill development in middle distance track. We would like to administer the study to a sample of approximately 200 male and female athletes representing different skill levels in the 800m, 1500m, and 3000m events. The information obtained from this data will enable us to meet our research objectives and, potentially, contribute to a more tangible description of talent development in middle distance track.

In accordance with the Faculty of Health Sciences ethical procedures, all the information that the participants give to us will remain confidential. Only those investigators immediately responsible for the research will have access to the data. Identification numbers have been inserted on the top right corner of all the pages that will be collected by the investigators. For the entire study, participants will be referred to by their respective identification number. The raw data, as well as the identification number of the respondents, will be stored separately in locked files. Inferences will be made on the results obtained from group data only and not on individual differences. The thesis will be written in such a way as to conceal the identity of all participants. Once the thesis has been accepted, the raw data will be destroyed. All steps will be taken to ensure the full confidentiality and anonymity of participants.

The study involves two parts. The first segment is a questionnaire about the athletes' practice activities in the past. It should take approximately 30 minutes to complete. The second segment is a diary. In order to complete this part of the study, we would like the participants to set aside approximately 10 minutes per day for seven consecutive days. All of the data will be entered into a computer in order to conduct statistical analyses.

It has been our experience that involvement in this study is a pleasant and educational task. This study will encourage the participants to trace their development in middle distance track and to engage in a diary activity that will subsequently provide them with feedback on time management. Upon completion of the study, all participants can request a summary of the findings as well as a description of their personal developmental profile. Should they wish feedback on their personal profile, this can be accomplished by requesting it in the diary booklet. We are confident that involvement in this study will be beneficial in improving participants' understanding of skill development in middle distance track.

We believe that athletes will find this study interesting and worth completing. This study has the potential to be beneficial for all those involved. Aspiring track athletes will be able to interpret findings in an instructional light. For those who have already achieved elite levels, it will serve as a reaffirmation of their training methods and as an opportunity to disseminate some of their knowledge to developing athletes. Finally, this study could contribute greatly to coaching and developmental institutions for middle distance track in Canada. Considering the potential benefits of this study, we certainly encourage you to give the athletes who are interested in becoming subjects, consent to participate in this research project. The athletes' participation in the study is entirely voluntary, but their responses would be extremely helpful and greatly appreciated.

If at any time an athlete wishes to withdraw from the study, he / she may do so freely without penalty of any kind.

As a representative of this club / organization / school, I give the athletes who are interested in becoming subjects, consent to participate in this research project.

Signature ______________________________ Date ______________________

Please contact us at any time for more information.

Bradley Young or **Dr. John Salmela**
University of Ottawa
School of Human Kinetics
125 University Private
Ottawa, ON, K1N 6N5
tel: (613)562-1051 or 562-5800 ext.4261

Dr. J. Roger Proulx
Chair of the Faculty of Health Sciences
Human Research Ethics Committee
Faculty of Health Sciences, University of Ottawa
451 Smyth Rd., Ottawa, ON, K1H 8M5
tel: (613)787-6705

APPENDIX B

Letter of Information

LETTER OF INFORMATION

Dear Athlete,

This study is part of a research project that is examining the causes of expert performance in sport. The University of Ottawa, in conjunction with Sport Canada and the Coaching Association of Canada, is studying talent development in high level competitive sport. We are now extending our efforts into the domain of middle distance track.

The process of talent development in sport remains an elusive phenomenon. The purpose of this research is to examine the relationship between both qualitative and quantitative aspects of practice and skill development in middle distance track. We would like to administer the study to a sample of approximately 200 male and female athletes representing different skill levels in the 800m, 1500m, and 3000m events. The information obtained from this data will enable us to meet our research objectives and, potentially, contribute to a more tangible description of talent development in middle distance track.

In accordance with the Faculty of Health Sciences ethical procedures, all the information that you give to us will remain confidential. Only those investigators immediately responsible for the research will have access to the data. As you will notice, an identification number has been inserted on the top right corner of all the pages that will be collected by the investigators. For the rest of the study, you will be referred to by this identification number. The raw data, as well your identification number, will be stored separately in locked files. Inferences will be made on the results obtained from group data only and not on individual differences. The thesis will be written in such a way as to conceal the identity of all participants. Once the thesis has been accepted, the raw data will be destroyed. All steps will be taken to ensure the full confidentiality and anonymity of participants.

The study involves two parts. The first segment is a questionnaire about your practice activities in the past. It should take approximately 30 minutes to complete. The second segment is a diary. In order to complete this part of the study, we would like you to set aside approximately 10 minutes per day for seven consecutive days. All of your data will be entered into a computer in order to conduct statistical analyses.

It has been our experience that involvement in this study is a pleasant and educational task. This study will encourage you to trace your development in middle distance track and to engage in a diary activity that will subsequently provide you with feedback on time management. Upon completion of the study, you can request a summary of the findings as well as a description of your personal developmental profile. Should you wish feedback on your personal profile, this can be accomplished by requesting it in the diary booklet. We are confident that involvement in this study will be beneficial in improving your understanding of skill development in middle distance track.

We believe that you will find this study interesting and worth completing. This study has the potential to be beneficial for all those involved. Aspiring track athletes will be able to interpret findings in an instructional light. For those who have already achieved elite levels, it will serve as a reaffirmation of your training methods and as an opportunity to disseminate some of your knowledge to developing athletes. Finally, this study could contribute greatly to coaching and developmental institutions for middle distance track in Canada. Considering the potential benefits of this study, we certainly encourage you to participate in it. Your participation in the study is entirely voluntary, but your responses would be extremely helpful and greatly appreciated.

The club / organization / school to which you are affiliated has granted us the permission to solicit you as a participant. Filling out the questionnaire and / or the diary would indicate that you freely consent to participate in this study.

If at any time you wish to withdraw from the study, you may do so freely without penalty of any kind.

Please contact us at any time for more information.

Bradley Young or **Dr. John Salmela**
University of Ottawa
School of Human Kinetics
125 University Private
Ottawa, ON, K1N 6N5
tel: (613)562-1051 or 562-5800 ext.4261

Dr. J. Roger Proulx
Chair of the Faculty of Health Sciences
Human Research Ethics Committee
Faculty of Health Sciences, University of Ottawa
451 Smyth Rd., Ottawa, ON, K1H 8M5
tel: (613)787-6705

APPENDIX C

Sample Questionnaire

ID# __________

Université d'Ottawa • University of Ottawa

Faculté des sciences de la santé
École des sciences de l'activité physique

Faculty of Health Sciences
School of Human Kinetics

Middle Distance Track Questionnaire
Biographical Information

Age:

Gender:

- How old were you when you began running? ______

- At what age did you begin regular practice for track with a coach? ______

- How old were you when you became involved more full-time or on a year round basis? _______

- Are you training competitively for the 1997 outdoor track season (Y/N)?

- What is the primary track event you are training for in 1997?

  ____

ID# __________

Please take a moment to read and understand each of the following activity labels. You will be asked questions about the following activities and it is important that you are clear as to what each label refers to.

Cross Training - includes cycling, treadmill running, stationary bike, pool workouts, and rowing ergometer work used to improve running performance.

Flexibility - traditional stretching exercises.

Mental Preparation - includes visualization/imagery, work on mental race plans, focus strategies, distraction control, goal setting exercises, relaxation/psych-up techniques, or consultation with a sport psychologist.

Easy Run - a continuous distance run that allows you to converse, i.e., "talk pace." This label also includes warm-up and cool-down runs. This type of training is intended to develop aerobic endurance.

Hard Run/Tempo Run - a continuous distance run that is faster than "talk pace." This type of training is intended to develop both aerobic and anaerobic endurance aspects of performance.

Long Interval Workout/Fartlek - this type of training is intended to develop both aerobic and anaerobic endurance aspects of performance. It involves alternating long intervals with short recoveries. The workout interval pace is at/slightly slower than the typical race pace of the primary distance (800m, 1500m, 3000m) the athlete intends to run.

Short Interval Workout - this type of training is intended to develop anaerobic speed/power and anaerobic endurance. This "speed work" involves alternating short intervals with long recoveries. The workout interval pace is faster than the typical race pace of the primary distance (800m, 1500m, 3000m) the athlete intends to run.

Race/Time Trial - competitive events or simulated race conditions.

Technique - striders, progressive accelerations, As, Bs, Cs, bounding exercises.

Weights (Power Training) - heavy loads with a low number of repetitions. This includes plyometrics, medicine ball, and traditional weightlifting exercises.

Weights (Endurance Training) - moderately low loads with a high number of repetitions. This includes circuits, medicine ball, body weight exercises, e.g., push-ups, sit-ups, abdominals, and traditional weightlifting exercises.

Work with a Coach - activities in which the coach is instructing you on topics relevant to improving your track performance. The coach must be specifically directing his/her instruction towards you as an athlete or aspects of your performance. Giving split times, providing encouragement, motivation, or the mere spectating presence of a coach are not included under this label.

Do not hesitate to consult this list at any time while you are filling out the questionnaire.

ID# __________

Training Log Consultation

Please use your personal training logs to complete the following activity. By using your training logs you ensure that your information is accurate.

We are interested in finding out what a **"typical week"** of training was like for you at different times in your **track** career. When you think of a "typical week", try to consider one occurring during the competitive phase of the track season. More specifically, **consider a "typical training week" that is 10 weeks prior to your major track championship.**

On the next page there is a chart with columns corresponding to different periods of your track career. Please write underneath the column headings the ages you were at the specific times. **Start Age should be the age when you first began to regularly practice running with a coach.** For example, if you started training at age 14, write Age=14 beneath the "Start Age" column, and Age=16 beneath the "2 Years Later" column, and so on. You may find that you will not need all the columns. If you have been training for more than 10 years you will require an additional chart on the following page. Please stop when you reach the column corresponding to the age you are now (or the nearest to it).

Each of the rows on the chart refers to a training activity. For each period in your career, **rate the relevance of that activity for the improvement of track performance** on a scale from 0 to 10. (0 = not relevant at all; 10 = extremely relevant) Next, recall the **average time (in minutes) in a typical week you spent practising that activity** at various periods of your track career. Next, **record the distances you covered (in kilometres)** for easy runs, hard runs/tempo runs, long interval/fartlek workouts, short interval workouts, and time trials/races respectively at various stages in your track career.

It is very important that you take your time and consider each time period and activity thoroughly. Again, if you have access to personal training logs, please consult them in order to complete this activity.

- Are you using the help of training logs in completing this chart (Y/N)?

ID# ____________

Practice Activity	Start Age			2 Years Later			4 Years Later		
	Age =			Age =			Age =		
	Relevance	Minutes/wk	Kilometres/wk	Relevance	Minutes/wk	Kilometres/wk	Relevance	Minutes/wk	Kilometres/wk
Cross Training			X			X			X
Flexibility			X			X			X
Mental Preparation			X			X			X
Easy Run									
Hard Run/Tempo Run									
Long Interval Workout/Fartlek									
Short Interval Workout									
Race/Time Trial									
Technique			X			X			X
Weights-Power Training			X			X			X
Weights-Endurance Training			X			X			X
Work with a Coach			X			X			X

Practice Activity	6 Years Later			8 Years Later			10 Years Later		
	Age =			Age =			Age =		
	Relevance	Minutes/wk	Kilometres/wk	Relevance	Minutes/wk	Kilometres/wk	Relevance	Minutes/wk	Kilometres/wk
Cross Training			X			X			X
Flexibility			X			X			X
Mental Preparation			X			X			X
Easy Run									
Hard Run/Tempo Run									
Long Interval Workout/Fartlek									
Short Interval Workout									
Race/Time Trial									
Technique			X			X			X
Weights-Power Training			X			X			X
Weights-Endurance Training			X			X			X
Work with a Coach			X			X			X

ID# ____________

Practice Activity	12 Years Later			14 Years Later			16 Years Later		
	Age =			Age =			Age =		
	Relevance	Minutes/wk	Kilometres/wk	Relevance	Minutes/wk	Kilometres/wk	Relevance	Minutes/wk	Kilometres/wk
Cross Training			X			X			X
Flexibility			X			X			X
Mental Preparation			X			X			X
Easy Run									
Hard Run/Tempo Run									
Long Interval Workout/Fartlek									
Short Interval Workout									
Race/Time Trial									
Technique			X			X			X
Weights-Power Training			X			X			X
Weights-Endurance Training			X			X			X
Work with a Coach			X			X			X

Practice Activity	18 Years Later			20 Years Later			22 Years Later		
	Age =			Age =			Age =		
	Relevance	Minutes/wk	Kilometres/wk	Relevance	Minutes/wk	Kilometres/wk	Relevance	Minutes/wk	Kilometres/wk
Cross Training			X			X			X
Flexibility			X			X			X
Mental Preparation			X			X			X
Easy Run									
Hard Run/Tempo Run									
Long Interval Workout/Fartlek									
Short Interval Workout									
Race/Time Trial									
Technique			X			X			X
Weights-Power Training			X			X			X
Weights-Endurance Training			X			X			X
Work with a Coach			X			X			X

ID# __________

What was the **duration of your off-season** (time not training for any type of running) at different times throughout your career? Again use only the columns that you need.

	Start Age	2 Years Later	4 Years Later	6 Years Later	8 Years Later	10 Years Later
Duration (weeks)						

	12 Years Later	14 Years Later	16 Years Later	18 Years Later	20 Years Later	22 Years Later
Duration (weeks)						

What were your **personal records of performance** for each of the following events at different periods in your career? Again use only the columns you need.

Event	Personal Records					
	Start Age	2 Years Later	4 Years Later	6 Years Later	8 Years Later	10 Years Later
800m						
1500m						
3000m						
Event	Personal Records					
	12 Years Later	14 Years Later	16 Years Later	18 Years Later	20 Years Later	22 Years Later
800m						
1500m						
3000m						

ID# __________

Next, you will be asked questions about the training activities you have already seen, plus additional track-related activities, and non track-related activities. Please take a moment to read and understand each of the new activity labels.

Conversing about Running - conversations outside of the training environment specifically about running with other athletes, agents, and administrators.

Coaching Track to Others - running instruction.

Diet/Nutritional Planning - monitoring your diet.

Physiotherapy - includes curative and preventative treatment for running related injuries. This label includes massage treatment.

Reading Running Material - books, magazines, articles, meet programmes.

Training Journal - upkeep and evaluation.

Organization and Preparation - includes changing for running, traveling to running related events, and maintenance of running equipment.

Watching Running - live, on television, or on film.

Active Leisure - other recreation, sports that are not intended to improve track performance. This includes any physically demanding activities outside of track training.

Nonactive Leisure - includes movies, computer leisure, e.g., internet/e-mail, correspondence with friends, e.g., talks, reading, parties, hobbies, TV, radio, bars, and physically nonactive functions that are not related to running.

Eating/Snacking

Sleeping - includes night sleep and short naps.

Studying/Working - seminars, courses, homework assignments, part-time, full-time employment, volunteer work, committee work, household chores, e.g., yardwork, preparing meals, cleaning, repairs, dishwashing.

Traveling/Commuting - traveling to non track-related locations.

Body Care and Health - washing, dressing, hygiene, visits to the doctor, therapy, physiotherapy for reasons other than track-related problems.

Do not hesitate to consult this list at any time while you are filling out the questionnaire.

ID# __________

"Rating your Practice"

On the next page there is a list of activities. Please rate each of the activities on the following four dimensions:

1) **Relevance**: the relevance of the activity to improving track performance.

2) **Effort**: how much physical effort is required to perform the activity.

3) **Enjoyment**: how enjoyable the actual activity is. **Please note that you are rating your actual participation in the activity, not the consequences of that activity.** For example, if we asked you to rate the enjoyment of household cleaning, the rating of the actual chore of cleaning would be lower than the consequences of the activity - a clean house. Keep this in mind when filling out the chart.

4) **Concentration**: how much concentration or mental effort is required to perform the activity.

For the purpose of rating, use a 10-point scale for all the activities.

For relevance, a "0" implies no relevance and a "10" means that the activity is the most relevant to improving track performance.

For effort, a "0" implies that no physical effort is required to perform the activity and a "10" means that the activity is extremely effortful.

For enjoyment, a "0" implies that the activity is not at all enjoyable and a "10" means that the activity is very enjoyable.

For concentration, a "0" implies that the activity requires no concentration and a "10" means that the activity demands very high levels of concentration.

ID# ______________

Activity	Relevance to Improving Track Performance 0 = no relevance 10= highly relevant	Effort Required to Perform the Activity 0 = no physical effort 10=high physical effort	How Enjoyable the Activity is 0 = no enjoyment 10= highly enjoyable	How Much Concentration is Required to Perform the Activity 0 = no concentration 10=high concentration
Cross Training				
Flexibility				
Mental Preparation				
Easy Run				
Hard Run/Tempo Run				
Long Interval Workout/Fartlek				
Short Interval Workout				
Race/Time Trial				
Technique				
Weights - Power Training				
Weights - Endurance Training				
Work with a Coach				
Conversing about Running				
Coaching Track to Others				
Diet/Nutritional Planning				
Physiotherapy				
Reading Running Material				
Training Journal				
Organization and Preparation				
Watching Running				
Active Leisure				
Nonactive Leisure				
Eating/Snacking				
Sleeping				
Studying/Working				
Traveling/Commuting				
Body Care and Health				

APPENDIX D

Figures for Accumulated Amounts of Practice in the Individual Training Activities

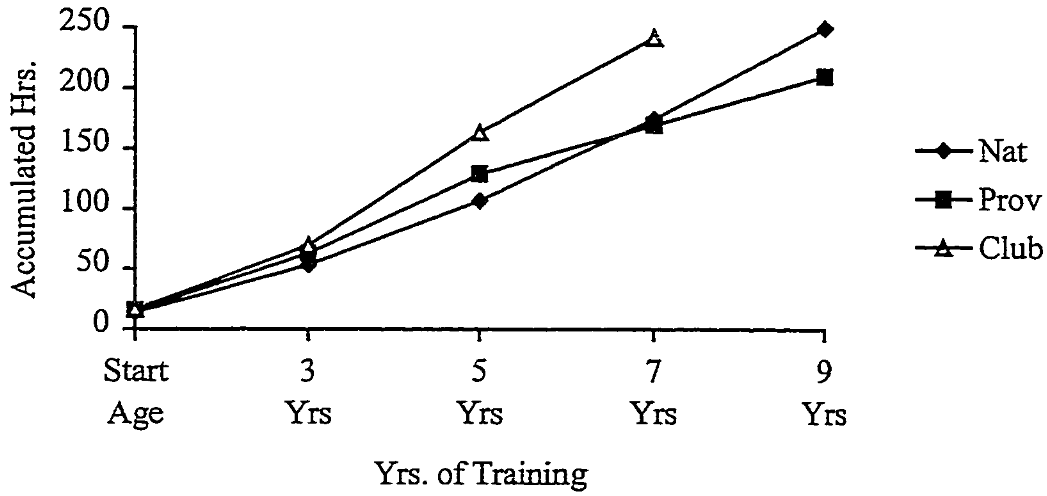

Figure 1. Accumulated amounts of practice for hard runs/tempo runs between performance groups over their careers.

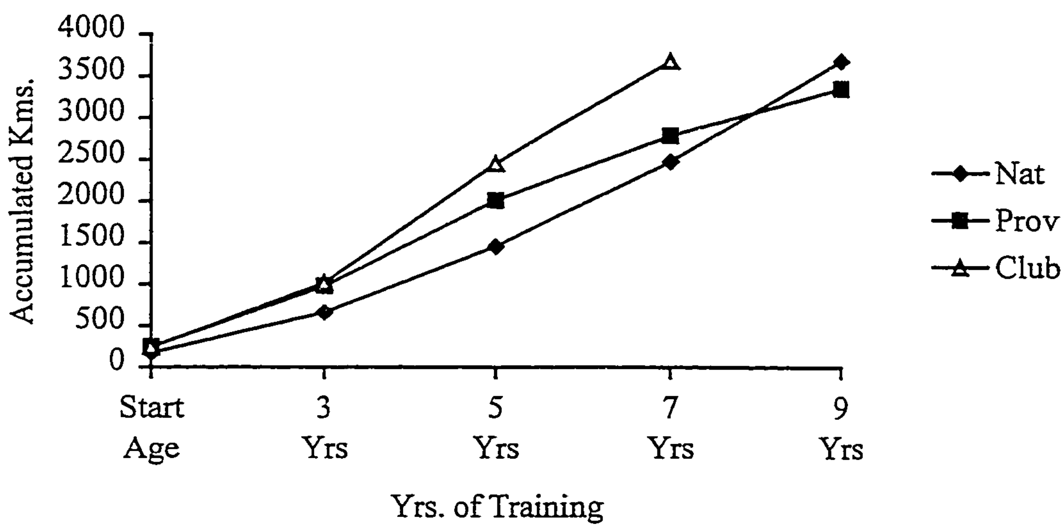

Figure 2. Accumulated kilometers run for hard runs/tempo runs between performance groups over their careers.

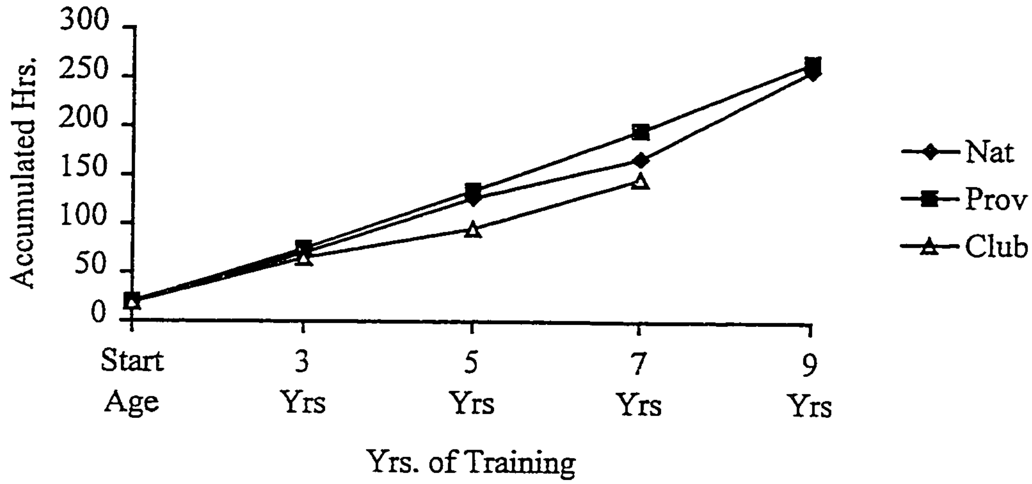

Figure 3. Accumulated amounts of practice for long interval workouts/fartlek between performance groups over their careers.

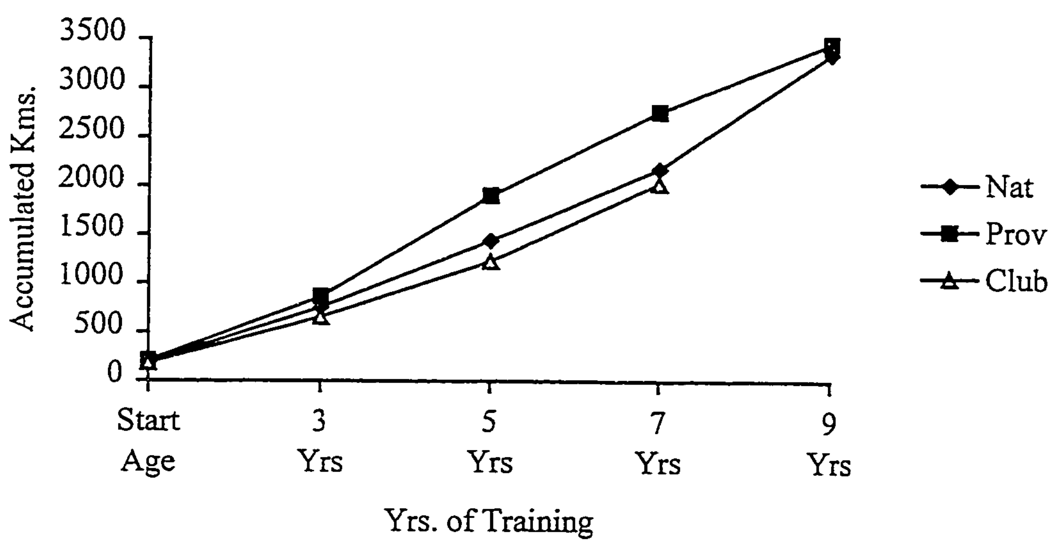

Figure 4. Accumulated kilometers run for long interval workouts/fartlek between performance groups over their careers.

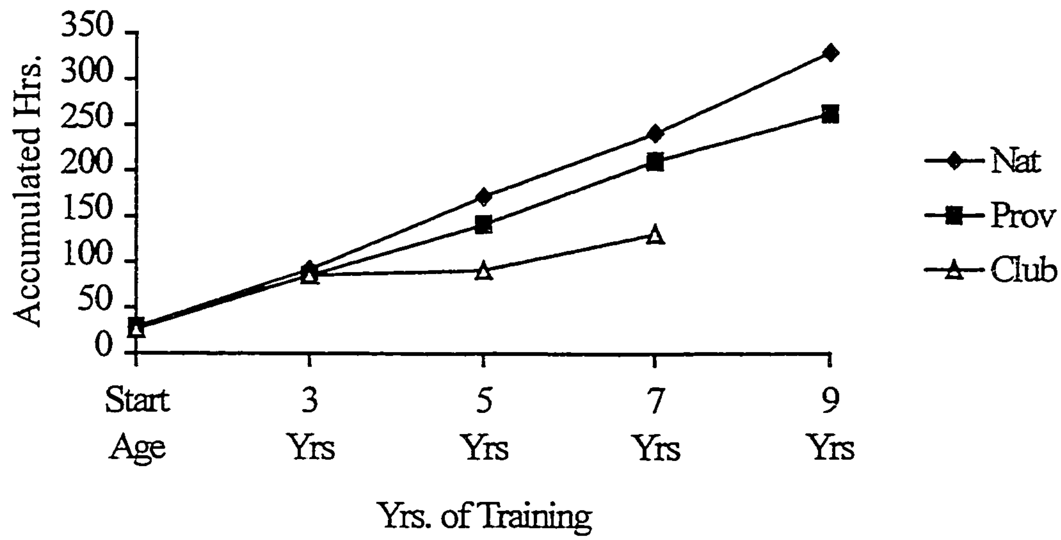

Figure 5. Accumulated amounts of practice for short interval workouts/speed work between performance groups over their careers.

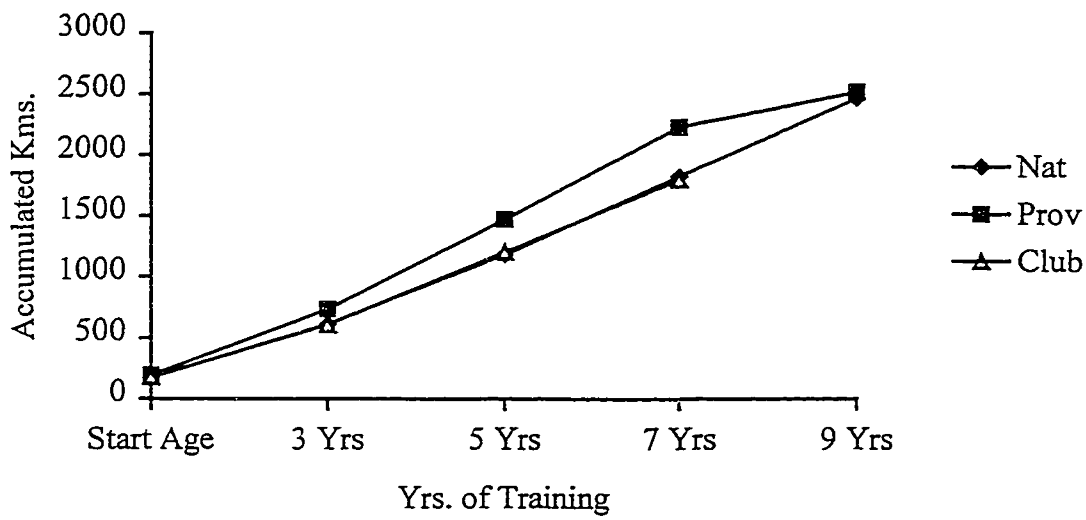

Figure 6. Accumulated kilometers run for short interval workouts/speed work between performance groups over their careers.

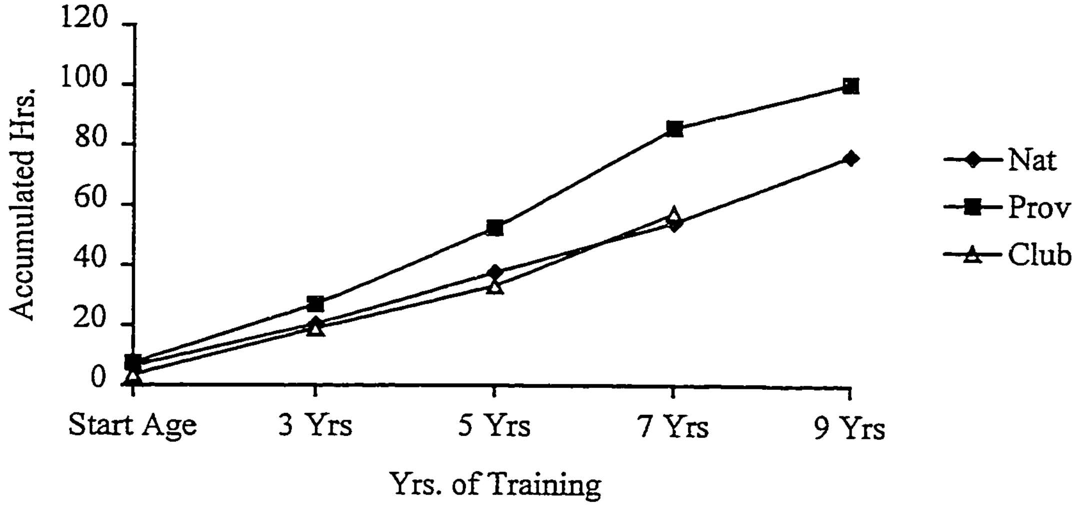

Figure 7. Accumulated amounts of practice for races/time trials between performance groups over their careers.

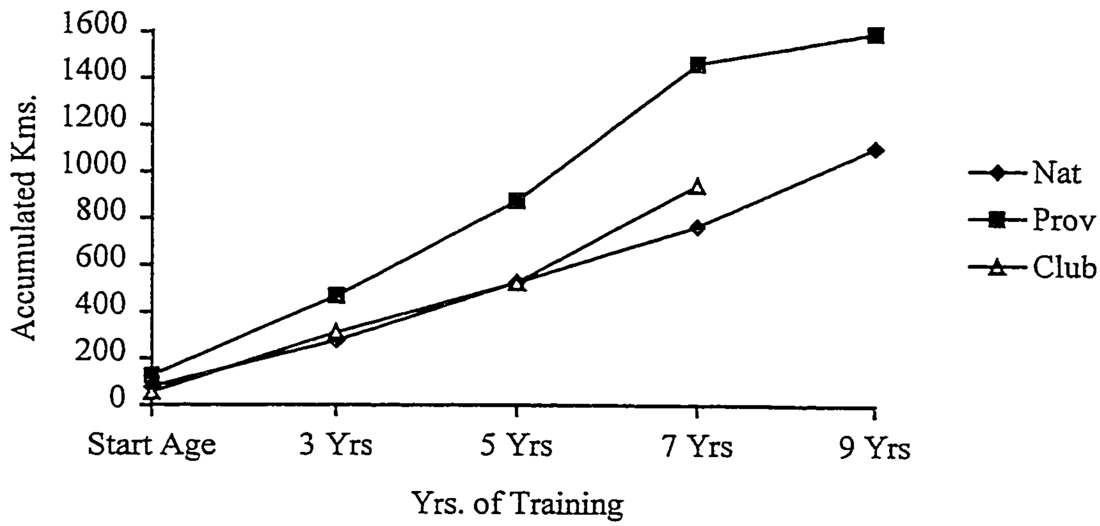

Figure 8. Accumulated kilometers run for races/time trials between performance groups over their careers.

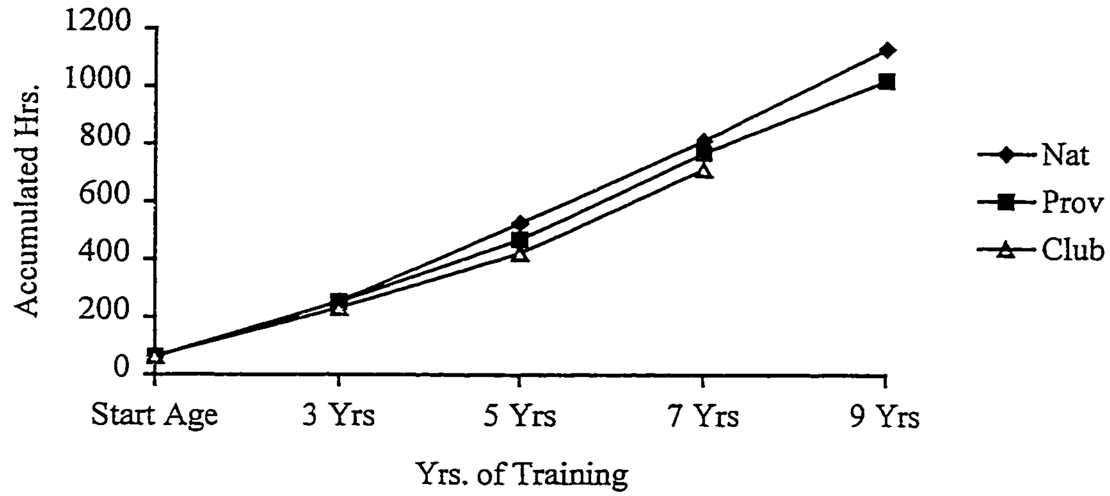

Figure 9. Accumulated amounts of practice for easy runs between performance groups over their careers.

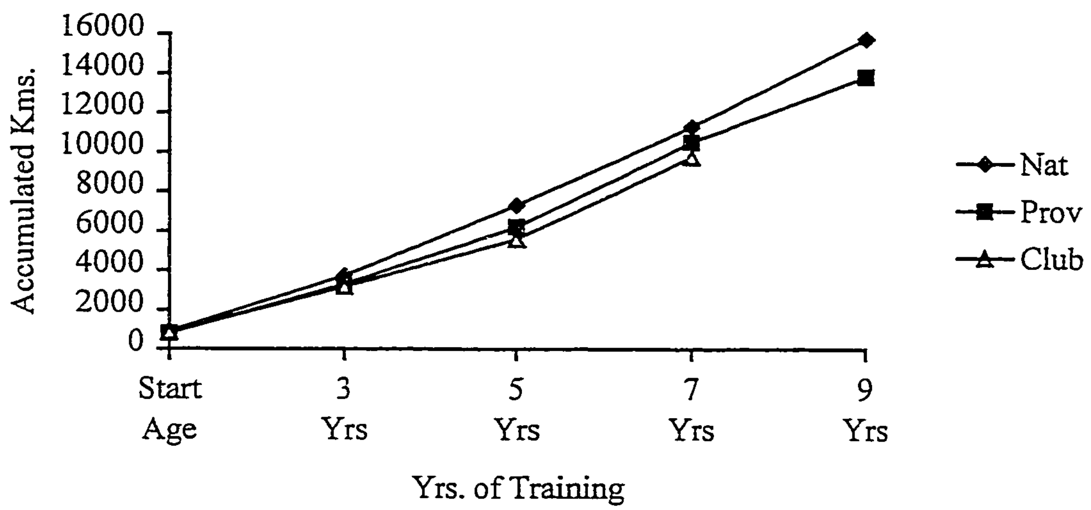

Figure 10. Accumulated kilometers run for easy runs between performance groups over their careers.

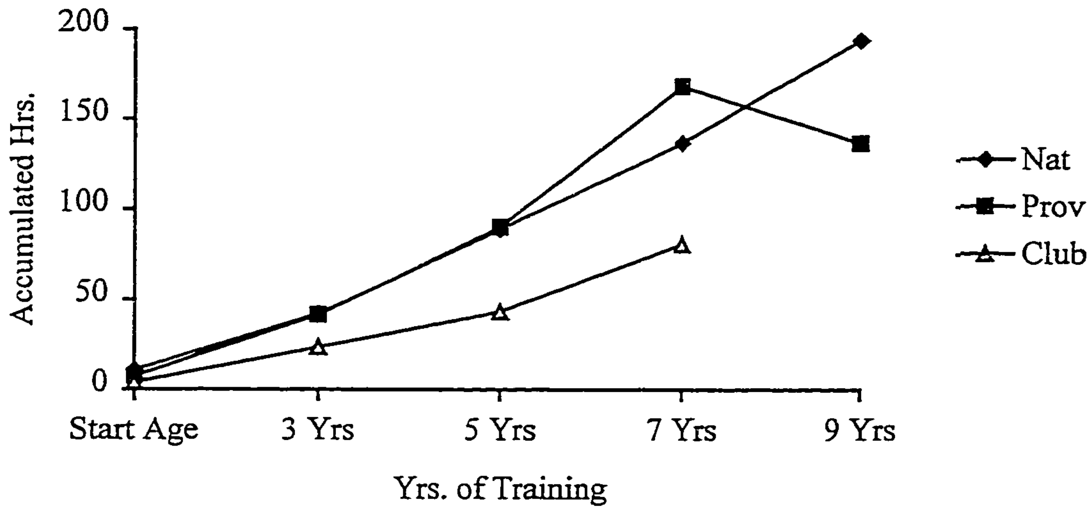

Figure 11. Accumulated amounts of practice for mental preparation between performance groups over their careers.

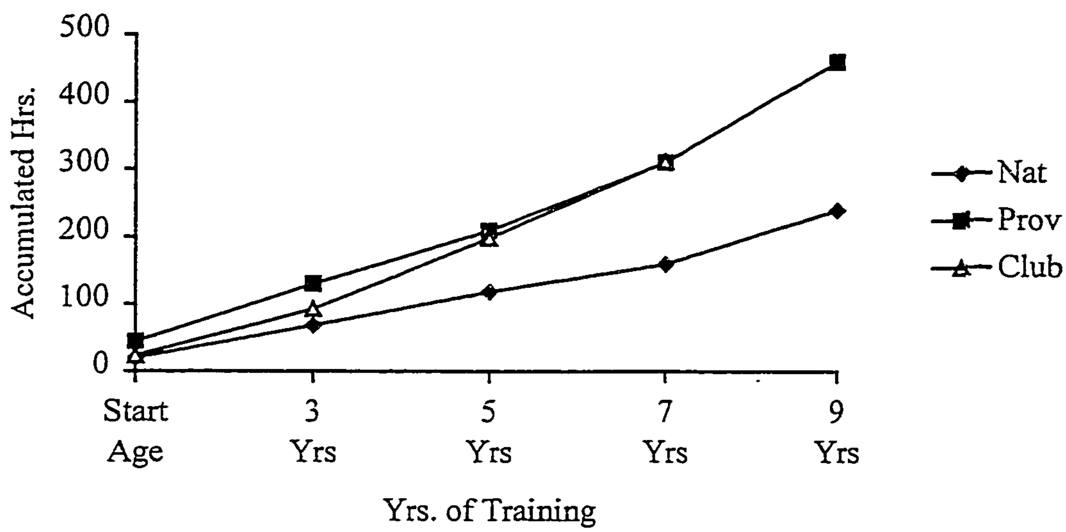

Figure 12. Accumulated amounts of practice for cross training between performance groups over their careers.

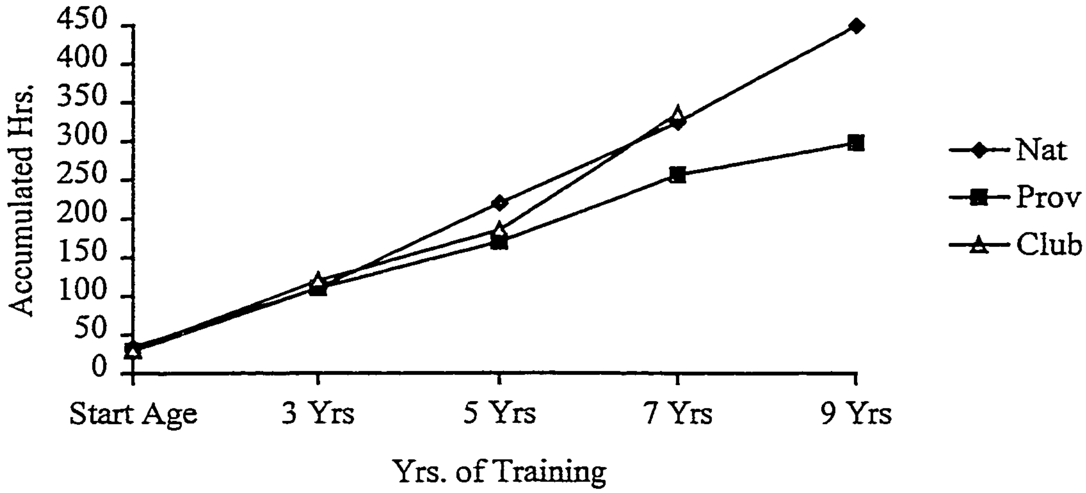

Figure 13. Accumulated amounts of practice for flexibility between performance groups over their careers.

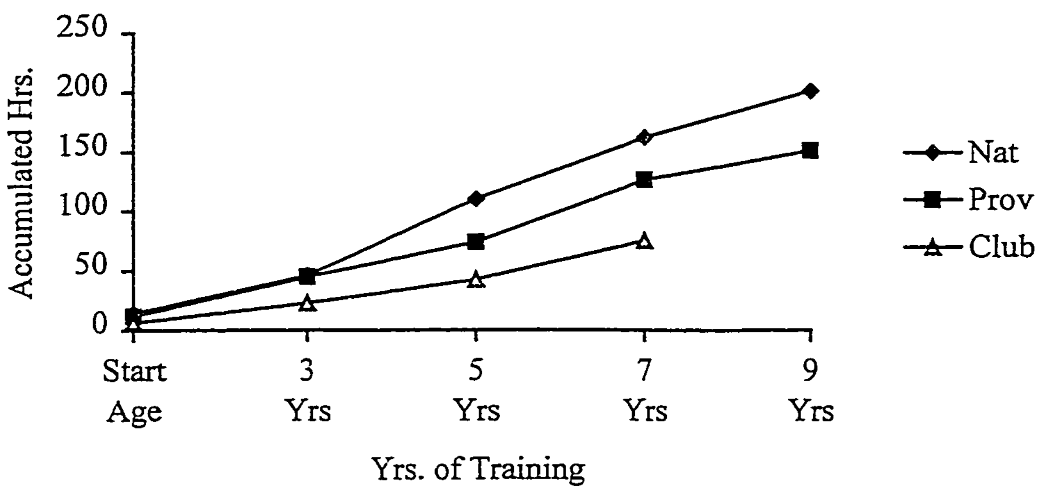

Figure 14. Accumulated amounts of practice for technique between performance groups over their careers.

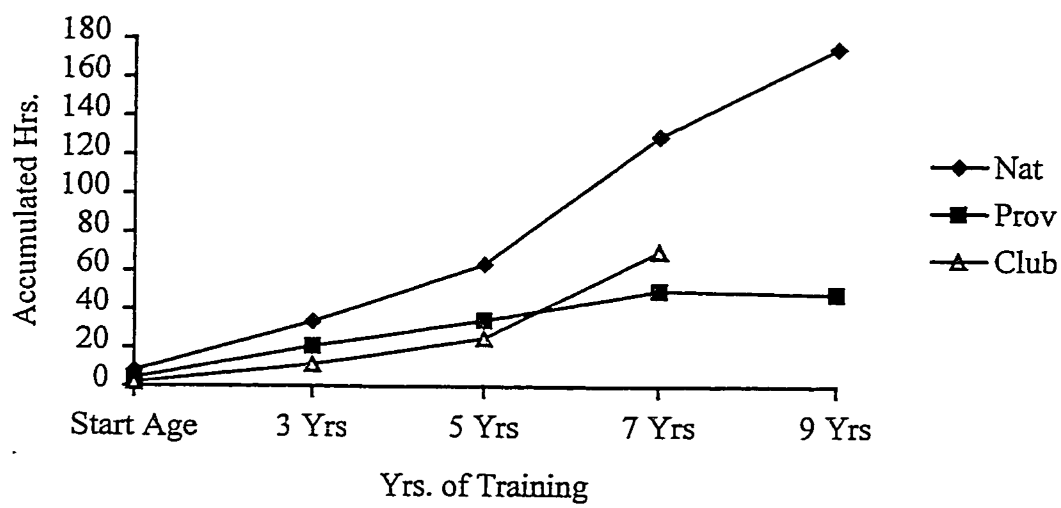

Figure 15. Accumulated amounts of practice for power weights between performance groups over their careers.

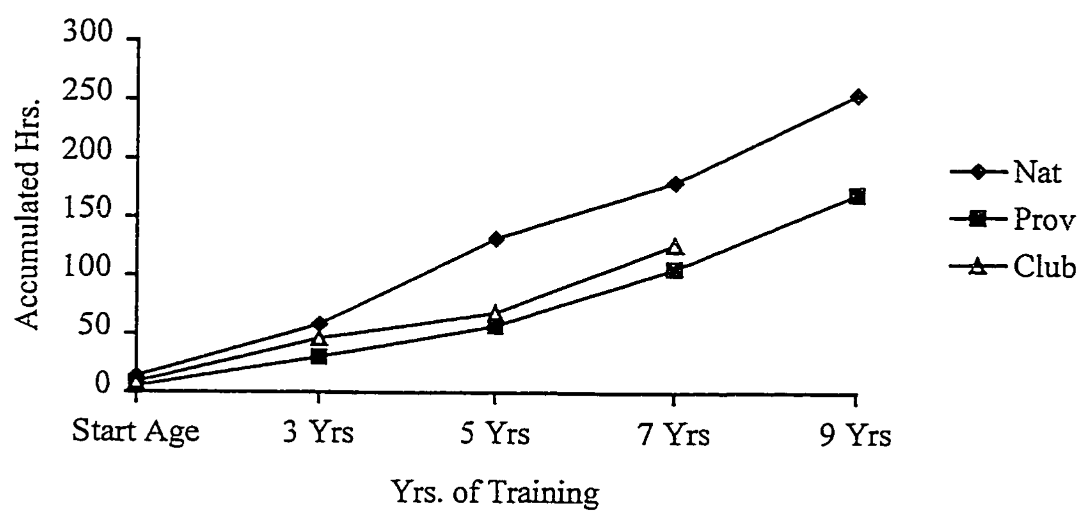

Figure 16. Accumulated amounts of practice for endurance weights between performance groups over their careers.

APPENDIX E

Ethics Approval Documentation

Université d'Ottawa · University of Ottawa

Faculté des sciences de la santé
Cabinet de la doyenne

Faculty of Health Sciences
Office of the Dean

April 18, 1997

Professors John Salmela, Pierre Trudel and Jean Côté
School of Human Kinetics
Faculty of Health Sciences
University of Ottawa
Montpetit Hall
INTRA

Subject: **Your project entitled "*The acquisition of exceptional performance in sport*"**

Dear Professors:

It is my pleasure to inform you that the Faculty of Health Sciences, Human Research Ethics Committee, after study of the documentation provided, concluded that your project met the appropriate standards of ethical acceptability and falls within CATEGORY 1A. But Item 7 should mention that there is a low level of stress in the task and the Consent Form should mention that the participant will received a copy of the signed form.

I hereby attach a copy of the certificate of clearance granted by the University Human Research Ethics Committee.

This certificate is valid for a period of one year from the time of issuance. I would also like to remind you that, in accordance with the policies of the UHREC, it is your responsibility to notify the Committee of any major changes in this project.

On behalf of the Committee, I wish you success in your project.

Sincerely,

J. Roger Proulx, Ph.D.
Chair, Human Research Ethics Committee

451, ch. Smyth
Ottawa (Ontario) K1H 8M5 Canada

451 Smyth Rd.
Ottawa, Ontario K1H 8M5 Canada

IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6″

APPLIED IMAGE . Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989