WRESTLING WITH THE NATURE OF EXPERTISE

WRESTLING WITH THE NATURE OF EXPERTISE: A SPORT SPECIFIC TEST OF ERICSSON, KRAMPE AND TESCH-RÖMER'S (1993) THEORY OF "DELIBERATE PRACTICE"

By

NICOLA JANE HODGES, BSc.(Hons)

A Thesis
Submitted to the School of Graduate Studies
in Partial Fulfilment of the Requirements for the Degree
Master of Science

McMaster University

MASTER OF SCIENCE (1995)	McMASTER UNIVERSITY
(Kinesiology)	Hamilton, Ontario
TITLE	Wrestling with the Nature of Expertise: A Sport Specific Test of Ericsson, Krampe & Tesch-Römer's (1993) Theory of "Deliberate Practice"
AUTHOR	Nicola Jane Hodges, B.Sc.(Hons)
SUPERVISOR	Janet L. Starkes, Ph.D.
SUPERVISORY COMMITTEE	Digby Elliott, Ph.D. Timothy Lee, Ph.D. Nick Cipriano, M.Sc. Fran Allard, Ph.D.
NUMBER OF PAGES	x, 197

Dedication

To Joan Elizabeth Heimbecker,

27th September 1968 - 30th March 1994.

Although you will never fulfill your dreams, your love and friendship will always live on in mine.

Hope, like the gleaming taper's light,
Adorns and clears our way;
And still, as darker grows the night,
Emits a brighter ray.
Oliver Goldsmith

I would also like to dedicate this thesis to my family, especially Mum and Dad, who have always been so supportive, loving, and understanding - Thankyou.

Abstract

Ericsson, Krampe and Tesch-Römer (1993) have concluded from work with musicians that expertise is the result of "deliberate practice". So how valid is this conclusion in sport? Four groups of wrestlers (n=42); 2 international and 2 club (current & retired) recalled the hours spent in wrestling activities since beginning wrestling. All groups had begun at a similar age ($\underline{M}$ =13.2 $\pm$ 0.6year) and had been wrestling for 10 years or more. Contrary to Ericsson et al., practice alone activities did not discriminate between the groups, only practice with others. At 6 years into their careers, the international group practised 4.5 hour/week more than the club wrestlers and at age 20 years the international wrestlers had accumulated over 1000 more hours of practice with others. Evaluations of wrestling activities showed that those judged as relevant, were also rated high for concentration and enjoyment. Diary data were collected from current wrestlers, however, no differences were found for time spent in wrestling activities. The international wrestlers spent longer travelling to practice, which reflected the necessity to train at a club with the best sparring partners. Practice with others yielded high correlations between estimates for a typical week and the

diary data for the international wrestlers only, suggesting a more consistent training schedule for this group. In conclusion Ericsson et al.s' definition of "deliberate practice" needs to be reconsidered. It is suggested that "maintenance" hours should be considered separately from practice, and that future studies focus on what it is that motivates people to practice.

Acknowledgements

There are a number of people who I would like to express my sincere thanks to for their help in preparing this thesis.

Firstly, I would like to thank my committee for their helpful comments and advice; Dr. Fran Allard, Nick Cipriano, Dr. Digby Elliott and Dr. Tim Lee. Special thanks must go to Nick Cipriano, for helping me to enrol wrestlers for the studies, as well as providing invaluable wrestling expertise. I would also like to especially acknowledge Dr. Digby Elliott for always being there to ask advice of, and for being such a great motivator, mentor and friend.

All the wrestlers who participated in these studies, as well as their coaches and the staff at The Canadian Amateur Wrestling Association (CAWA).

Thanks also to the graduate students in Kinesiology who have put up with me for the last two years. No-one could ask for a nicer, friendlier and fun bunch of people to work with (and live with). You guys have been my family away from home, and I am very grateful for your love and friendship. Special thanks to Jim Lyons, who has patiently and critically listened to at least seven presentations of this work, but who has always been willing to listen to just one more. Also to Mary Cleland, the graduate secretary, who is always so kind and caring and willing to help at all times.

Finally and most importantly I would like to thank my supervisor, Dr. Janet Starkes, for always believing in me, and for bringing out my best work. You have been a great advisor and motivator and I feel very privileged to have worked with you, thank-you.

Table of Contents

List of Tables

List of Figures

Introduction

Although no one would deny that practice is a necessary mediating factor for the attainment of expertise, to make the claim that practice actually causes expertise, and is therefore both a necessary and sufficient condition, would lead to much disagreement and controversy. This extreme environmental position, however, has recently been adopted by Ericsson, Krampe and Tesch-Römer (1993), who have proposed a theory of expertise based solely on what they term "deliberate practice". "Deliberate practice" is defined as any activity designed to improve the current level of performance, that is effortful and not inherently enjoyable. It is contrasted to other activities that could erroneously be considered practice, that is, play, work, and observing others performing the skill. Ericsson et al. propose that, "the amount of time an individual is engaged in deliberate practice activities will be monotonically related to that individual's acquired performance." (p.368). Within their theory they allow no important role for inherent characteristics in determining the achievement of expertise. This suggestion that innate characteristics are unnecessary to achieve expert levels is a particularly salient issue when considering expert athletes,

who "appear" to be born with superior bodies and physiological capacities that underlie their exceptional performance.

There have been numerous studies, stemming from the seminal work of Chase and Simon (1973) in chess, that have demonstrated the primary role of acquired domain specific skills in differentiating novices and experts (e.g., Abernethy, Neal & Koning, 1994; Allard, Graham & Paarsalu, 1980; Baba, 1993; Lesgold, Rubinson, Feltovich, Glaser, Klopfer & Wang, 1988). Investigations of developmental histories of experts have also highlighted the importance of environmental factors. Most notably, Bloom (1985) edited a unique book detailing the careers of experts from 6 domains. A surprising amount of consistency between the histories of the experts across different domains was observed. Specifically, the early age of starting, the parental involvement and the stages of development were all similar. From the six domains studied, ranging from music to mathematics, Bloom concluded that no matter what the quality of the initial gifts, each individual goes through many years of development, and that "practice and training time rivalled the time devoted to school or any other activity." (p.543). However, until now the role of initial ability or "talent" has never been completely discounted.

At the other end of the continuum, there are those who claim that individual differences in ability determine who will achieve eminent performance. From the early work of

Galton (1892), who advocated the importance of initial gifts that determine the limit of an individual's success, to Gardner's (1983, 1993a, 1993b) recent theorizing about multiple intelligences, many researchers have expounded this view. There is also considerable genetic evidence pointing towards a strong heredity component for many observed skills and traits. Studies with twins, for example, have provided evidence for the heredity of intelligence, physical characteristics and psychomotor abilities (e.g., Bouchard, 1984; Engostrom & Fischbein, 1977; Marisi, 1977 respectively).

Unfortunately the type of study conducted has been limited in its design, and often reflects the viewpoint of the researcher. That is, those who believe that expertise is the result of inherited abilities will generally test this hypothesis by examining familial relationships (e.g., twin or adoption studies), to see how much variance between twin pairs on a specific performance measure can be accounted for by heredity. Whereas those who wish to demonstrate that expert - novice differences are due to knowledge, or physical characteristics acquired while working within a domain will be more likely to conduct cross-sectional studies comparing experts and novices on domain specific tasks or attributes. However, both these perspectives are limited by the designs employed to test their hypotheses, in that cross-sectional, correlational and retrospective studies do not allow for direct manipulation of the independent variable, so that

inferences concerning causality are limited. Longitudinal prospective studies of subjects who become experts would provide the most enlightening source of information regarding possible physiological/genetic limits and the importance of practice behaviours. However, there are very few of these types of studies as the continual investigation of a great many subjects is required, with the possibility that none of the subjects continue within the domain long enough, or ever reach a level where they would be considered an expert.

In sports the nature of expertise is an extremely important topic, given that considerable time, money and energy are spent in selection and identification of "talented" individuals who are presumed to have the potential to succeed in a specific sport. If it is found that sport expertise is a consequence of "deliberate practice", rather than innate ability, the implications for the selection of athletes at a young age are enormous. Now, the emphasis would centre on identifying those individuals who are believed to have the qualities, such as motivation and commitment, necessary to put in the hours of practice to achieve expertise. As well as trying to determine what "deliberate practice" activities are for each domain.

In the following review of literature evidence for and against a theory of expertise based solely on practice will be examined. First, theories and evidence supportive of innate talent and individual differences in abilities that are

believed to determine future success will be detailed and evaluated. The evidence that has lead Ericsson et al. to propose their theory will then be reviewed along with the specifics of Ericsson et al.s' theoretical framework. Two studies with musicians have been conducted by Ericsson et al. to directly test their theory and these will be detailed and considered in light of an empirical test of the model in sport.

Contradictory Findings and Alternative Theories

Cognitive and Perceptual Evidence

Although there has been some compelling evidence to suggest that memory ability is entirely an acquired skill (Chase & Ericsson, 1982; Ericsson, Chase & Faloon, 1980) recent evidence has come to light that questions this assumption. Wilding and Valentine (1994) have investigated memory ability for a number of years and now believe that not all the available evidence on superior memory ability can be accounted for by the utilisation of memory strategies. They suggest that there is a "natural" memory ability and that it may be evidenced by superior performance on tasks not suited to mnemonic techniques, superior ability in close relatives, demonstration of superior ability at a young age, exceptional incidental long-term memory and possibly the possession and use of vivid imagery. Their evidence for natural ability in memory was obtained from ten contestants recruited from the World Memory Championships.

The subjects were asked questions regarding their beliefs about their memory performance and whether they practised, as well as details about relatives' memory and their imagery ability. Only one subject answered "no" to the question, "do you think you have a naturally good memory?" and only four of the contestants reported practising regularly. This could, however, be a bias on the part of the subjects, to attribute cause internally for success. The percentage of near relatives having superior memory was reported to be 50%. Subjects were also tested on a battery of tests which included immediate and delayed story recall, recall of names of British prime ministers, measures of verbal and imaginal thinking and recognition of snow crystals amongst 70 foils. There were 13 tests altogether.

The results showed a number of interesting findings. The first couple of subjects demonstrated superior memory only on tasks they had a special interest in and subjects C. and H. were only proficient on tasks that were amenable to practised memory techniques, so their performance on the story, picture location and sequence and snow crystals was not particularly impressive. Subject H. also demonstrated particularly poor performance on delayed recall. Subject D. on the other hand reported using no techniques yet demonstrated impressive performance on the tasks that subjects C. and H. had trouble with. Subjects G. and I. appeared to demonstrate good all round performance, which Wilding and Valentine considered to

be the result of natural ability and efficient application of techniques.

An analysis of variance on mean ranks for the tasks comparing subjects who clearly believed their performance was dependent on natural ability and those who reported using specific strategies was performed and as predicted an interaction was observed between task type and group. These findings suggest that there is some role to be played by natural ability in memory performance, and that the learning of strategies to aid performance may be limited to particular tasks. Whether extensive practice can compensate for lack of natural ability is questionable.

Case histories of special abilities of monosavants, that is individuals with a low IQ who have developed an exceptional skill in a particular area compared to the "normal" population, also present a problem for a theory based on "deliberate practice" alone. Sloboda, Hermelin and O'Connor (1985), detail the musical ability of an autistic savant "NP". When people close to "NP" were asked about the development of his skill it was reported that he had received few, if any, opportunities to play a musical instrument or encouragement to sing. At age 6 his "ability" was noted when he spontaneously reproduced a song on the piano that someone had just played. From then on he was given many opportunities to play although verbal instruction was never given. Information concerning how "NP" could have acquired his

knowledge is lacking, however, Sloboda does suggest reasons why the performance of "NP" considerably improved after that point. He suggests that due to a high intrinsic motivation which was almost obsessional, "NP" spent many hours of practice at the task and that just being exposed to music via the TV or radio could account for the original interest. Indeed, Ericsson and Faivre (1988) claim that these monosavants are relying on mechanisms that trained memory subjects also use such as chunking.

Howe (1989) also cites cases of monosavants in calendar counting and argues that because a general cognitive ability cannot be accepted as a cause for exceptional memory, it must be a specific cause such as these individuals spending many hours just thinking about calendars that most people would find uninteresting. However, it is also possible that the brain is partitioned into specific independent modules that would lead to superior ability in one area but poor functioning in a similar one. A similar explanation of intelligence has been expounded by Gardner (1983) for normal individuals and those perceived to be "geniuses".

However, Hill (1978, as cited in Howe, 1989) in a survey of monosavants noted that most of them have more than one special skill. For example "Harriot", who was astoundingly musically accomplished, could also recall about three hundred telephone numbers as well as calendar calculating over a 35 year range.

The ability to recognise pitch, in the absence of context for that sound, so termed "perfect" or "absolute pitch", has long been considered an inherent ability that discriminates the musically talented from the average musicians, as this skill is found in only a small proportion of musicians. More recently, however, the importance of this ability to music has been questioned and evidence has begun to emerge regarding the trainability of this skill. For example, Sloboda, Davidson and Howe (1994) have examined musicians and claim that this ability is not necessary for reaching the highest levels of musical accomplishment. As well, Levitin (in press, as cited in Sloboda et al., 1994) argues that when perfect pitch has been assessed, two independent areas are being measured, that is pitch memory and pitch labelling. When only pitch memory is assessed, in the absence of the need to label, over 2/3rds of a sample of college students demonstrated some evidence of absolute pitch. Cohen and Baird (1990) suggest that the reason why so few people acquire this skill is because it is rather like acquiring a second language, in that if it is learned as a child then learning will be easy relative to learning as an adult. They claim that there may be a critical period for acquiring this skill, after which the ability to distinguish pitches from other pitches (relative pitch) becomes the most important musical skill.

Although the cognitive-perceptual evidence reviewed here is suggestive of necessary innate characteristics that potentiate expert performance, the data are far from conclusive. It is necessary to consider other attributes that are particularly pertinent to sports to determine whether individual differences in motor abilities are predictive of performance on tasks that would appear to require these abilities.

Evidence for Innate Motor Abilities

There have been researchers who proposed the idea of a "general motor ability", that eventually lead to the development of tests of general abilities (e.g., the Barrow motor ability test, McCloy's general motor ability test, Cozen's athletic ability test) as well as the development of the idea of "motor educability", a term developed by Brace (1927). On the opposite side there have been researchers who have refuted the idea of a general motor ability and instead have proposed a specificity hypothesis of motor ability (e.g., Henry, 1961). The idea of a general motor ability, although a convenient proposal, has not actually achieved much support (e.g., Gross, Griessel & Stull, 1956; Henry, 1961; Singer, 1966). Much of the evidence against a general ability has been in terms of low correlations between different abilities that may at first appear to require similar skills, e.g throwing and kicking (Singer, 1966) and RT and MT (Henry, 1961). However, recent research by Keele and his associates

has lead to the proposal of general abilities in characteristics not often considered; timing, sequencing and force control (Ivry & Keele, 1989; Jones, 1993; Keele, Cohen & Ivry, 1990; Keele, Ivry & Pokorny, 1987; Keele, Pokorny, Corcos & Ivry, 1985). They propose that skills can be broken down into components controlled by different modules in the brain and thus termed it the "modular approach". Their view is based on the idea that the brain is organised by function, and two different tasks may require the same common function such as the regulation of force.

Keele and his colleagues have proposed three separate modules in the brain, although they appreciate that there may be more. Keele et al. (1985) examined the idea of a common timing mechanism. They demonstrated, via a tapping task, that timing accuracy correlated across different effectors, that is the foot and finger ($\underline{r}$ =.90), and also that timing judgements were related to subjects' ability to produce taps accurately spaced ($\underline{r}$ =.53). Keele et al. also found that skilled piano players demonstrated less variability than non-pianists for both perception and production of timing tasks. Although this finding suggests an underlying ability, it does not rule out the possibility that this is a skill acquired through practice, especially as Ericsson et al. (1993) found that accumulated practice on the piano could predict performance on simple finger tapping tasks. Similar evidence has been

demonstrated for force control (Keele et al., 1985) and sequencing (Keele et al., 1990).

Two other types of evidence lend support to this theory. First, from a neuropsychological perspective, timing has recently been linked with the cerebellum (Ivry & Keele, 1989). It has been found that only cerebellar patients were impaired on both a perceptual and a production timing task compared to brain impaired controls. Second, there is the phenomenon of clumsiness. The abilities approach to motor learning would suggest that people who are high on certain abilities will achieve superior performance in a number of tasks. Consummate to this, individuals who have low levels of ability will perform poorly on motor skill tasks (Jones, 1993). Therefore, is there a group who demonstrates this poor performance, and at the same time scores poorly on modules that are supposed to measure these basic abilities? Clumsy people would appear to fit into this category and indeed when a group of clumsy children were compared to a normal control group and tested for timing, it was found that for both production and perception the clumsy children displayed poorer ability (Williams, Woollacott & Ivry, 1989, as cited in Jones, 1993). Likewise, there was also suggestive evidence of poor force regulation amongst clumsy children (Lundy-Ekman, Ivry, Keele & Woollacott, 1991).

If these abilities represent unmodifiable traits, then training in these skills should not make a difference to

performance. In a recent unpublished study Jones found that although performance on a tapping task improved with practice, that is, decreased in variability even for intertap intervals not practised, the training did not transfer to a perception timing task. This presents problems for the modular approach, in that although it suggests that basic abilities cannot be trained, it could equally mean that improvements in performance are task specific. It could also mean that perhaps the module of "timing" is still too general to be proposed as an ability. This suggestion that abilities are more specific has received much attention from Fleishman, whose ideas have recently been expanded upon by Ackerman (1988).

Fleishman has been responsible for identifying individual differences in several abilities using factor analyses, so that performance could be predicted on complex tasks such as flying a plane (e.g., Fleishman, 1966; Fleishman, 1972; Fleishman & Hempel, 1955; Fleishman & Quaintance 1984). Fleishman and Hempel (1955) in one of their first experiments tested 264 subjects on 9 tests measuring motor abilities and then asked the subjects to perform a more complex discrimination motor task. They found that performance on the task was related to different tests of abilities at different levels of practice. For example, spatial ability accounted for 36% of the variance in performance at the start of practice, but this decreased to

11% at the end of practice and other abilities became more important (e.g., rate of arm movement).

Ackerman (1988) has put together an integrative theory, whereby early skill acquisition theories, e.g., Fitts (1964), Fitts and Posner (1967); Anderson (1982), are combined with research regarding individual differences in ability. One of the consequences of this integration is the notion that because the learning of a motor skill passes from a cognitive to an automatic/procedural stage, cognitive ability such as "reasoning" will predict initial performance on a motor task. Although this proposition is common to both Fleishman's and Ackerman's research, Ackerman details more specifically how the influence of cognitive abilities is dependent on the complexity of the task and the consistency of learning. He also proposes that after practice at a task, individual differences in basic ability, such as intelligence, can still account for a great deal of variance between individuals, which was not suggested by Fleishman. That is, if the initial productions are not formulated effectively early in learning, cognitive ability will still account for individual differences at extended levels of practice. This idea is contrary to that predicted by Ericsson et al. who claim that individual differences after extended practice will be the result of differences in time spent in "deliberate practice".

Ackerman proposes three types of abilities that differentiate between individuals at different phases of motor

skill acquisition. These are general intelligence, perceptual-speed ability and psychomotor ability. According to his theory the role of these abilities diminishes or increases depending on the stage of learning. That is psychomotor abilities, such as simple reaction time (SRT), do not differentiate individuals until they have had considerable practice at a task. Thus, at the same time as these increase in predictiveness, the role of perceptual-speed abilities diminish. Ackerman has tested his predictions using an air traffic control simulation and has demonstrated considerable support. It is worth noting, however, that the learning tasks, although substantial for a laboratory training situation, are by no means comparable to the ten years of practice that Ericsson et al. propose are necessary to achieve expertise in real-world domains. Indeed, whether individual differences in general abilities limit the acquisition of expertise has not really been addressed in this work. Although Ackerman finds that something like SRT correlates highly with performance on a complex discrimination RT task after 800 trials, no such relations are found when cross-sectional studies comparing real world expert and novices are performed (e.g., Starkes & Deakin, 1984). Garland and Barry (1990) also suggest that after continued exposure to a sport, individual differences in abilities are no longer important. Indeed, early studies (e.g., Trussel, 1965, in juggling)

demonstrated the poor relationship between initial performance and later achievements.

Genetic Evidence

General introduction

The toughest evidence for any theory that proposes a primary and indeed overwhelming role of the environment, is genetic evidence to the contrary. The strongest genetic research is based on the twin model, especially the demonstration that MZ twins, when reared apart, still show significant correlations for many characteristics. Ericsson et al.s' model only allows for the genetic determination of height as an important component in the acquisition of expertise in sports like volleyball or basketball. However, even in basketball there are still people who play professionally who have circumvented, to a degree, this height constraint and play basketball even though they are under 6 ft. tall. Even individuals who sustain serious physical injuries are able to overcome these and make it back to the top level of competition (e.g., Silken Laumann, the Canadian rower who broke her leg, then went on to win silver at the Olympics) or achieve amazing physical endeavours (e.g., Terry Fox).

There have been many studies, however, that strongly indicate a significant role for genetics in the determination of many abilities that would be necessary to acquire expertise in many domains, and that would appear to give individuals a

headstart in the learning process. Galton (1875) introduced the twin-study method to distinguish between the roles of the environment and inherited characteristics. His research, which involved examination of both physical characteristics such as height and strength, as well as psychomotor characteristics, such as RT, led him to the following conclusion (as cited in Bouchard, 1984, p. 147)

> There is no escape from the conclusion that nature prevails enormously over nurture when the differences of nurture do not exceed what is commonly to be found among persons of the same rank of society and in the same country. My fear is, that my evidence may seem to prove too much and be discredited on that account, as it appears contrary to all experience that nurture should go for so little. (1875, p. 576).

Although this opinion would now be viewed as extreme, there are still many researchers who believe that nature has a significant role to play in the acquisition of expertise.

Cognitive evidence

In a recent review of family and twin studies examining cognition and heredity, Plomin (1988) concluded that as much as half the variance in IQ scores is due to genetic variation. The most recent study on twins and genetic determination of IQ has been the Minnesota Study of Twins Reared Apart (Bouchard, 1984). Analyses have yielded a correlation of .58 for performance on the Raven's Progressive Matrices and .78 for the Mill Hill. These correlations are comparable to those of MZ (monozygotic) twins reared together and are considerably greater than those for DZ (dyzygotic) twins reared together, .19 (Raven's), .37 (Mill Hill).

Physiological evidence

Although considerable data are now available on the adaptability of the physiological system, it is also necessary to review the evidence that individuals are limited by their physiological characteristics and that no matter how hard someone trains, they will never surpass a threshold determined by their genetic make-up. For example, Prud'homme, Bouchard, LeBlanc, Landry and Fontaine (1984) submitted 10 pairs of non-trained MZ twins to a 20 week endurance training program to determine whether the sensitivity of maximal aerobic power (MAP) to aerobic training was genotype-dependent. The twins increased their aerobic and anaerobic power significantly after training. More interestingly, however, the intraclass correlation coefficient for VO_2max was .74 between the twin pairs. This finding strongly suggested that sensitivity to training was genotype-dependent. As well, some of the individuals did not improve or gained very little with training. This result was further supported by Klissouras (1973, as cited in Klissouras, 1976) who highlighted the case of a pair of DZ twins, where one was a competitive runner yet had a VO_2Max lower than that of his untrained brother. Klissouras (1976) concluded from this observation that,

> The implicit postulate of this observation is that some individuals with a weak genotype have to use a greater amount of physical activity to attain an average adaptive value, whereas those with generous native endowment may not need more than a threshold exposure to maintain their already high adaptive value. (p. 196).

Hamel, Simoneau, Lortie, Boulay and Bouchard (1986), who gave 15 weeks of endurance training to 6 pairs of MZ twins also found that VO_2max was 4.6 times more similar within twin pairs than between. Although these findings highlighted possible genetic limitations, improvements with training for aerobic capacity (i.e., VO_2max) were observed. However, Hamel et al. failed to find any training effects for muscle fibre type, although the findings from past studies suggested that endurance training for a longer period than 15 weeks was needed to change fibre type.

Psychomotor abilities and physical characteristics

Malina (1984) examined similarities between twin pairs ranging from 3 to 18 months old on the Bayley test of motor development. He found that MZ pairs were more concordant than DZs, although the differences between the correlations decreased with age, indicating that maybe practice or experience modified performance on these measures. However, Engostrom and Fischbein (1977) measured strength concordance in pairs of MZ and DZ twins and found that the correlations were .83 and .47 respectively and that even after controlling for leisure time these correlations only slightly decreased to .80 and .33. Similar evidence for heredity of strength has been found among sibling and parent-child pairs (Monotoye, Metzner & Keller, 1975).

By examining familial relationships, Ishidaya (1957, as cited in Malina, 1984) proposed that 40 - 45% of the

variance in the 50m dash could be accounted for by genetics. In a relatively uncomplex sport like sprinting, one might expect a limit in the attainment of expertise due to a physiological limitation in explosive strength for example, or muscle fibre type. Indeed, Kovar (1981) found that estimates for heritability decreased with distance, that is .83 for the 20m dash, .62 for the 30m and .45 for the 60m dash.

Eastern European studies have also provided evidence of a significant role of genetics in running and jumping (Kovar, 1974; Sklad, 1973; Weiss, 1977; as cited in Malina, 1984). The triple jump was found to be the exception and this was suggested to be due to the amenability of the sport to training. Indeed, Marisi (1977) estimated heritability to be .96 on a pursuit rotor task, after testing 70 pairs of twins, however, this estimate decreased to .45 after 30 practice trials. Although obvious effects of training were evident, the heritability score was still high. It remains of interest, however, to see at what point during training either heritability estimates reach zero or stop decreasing.

Malina and Mueller (1981) conducted an extensive investigation of school children in Philadelphia to determine the genetic and environmental influences on motor performance. Malina and Mueller measured both strength and motor performance variables such as the 35yd dash and standing long jump of sibling pairs. They found that heritability estimates for grip strength were considerably high as well as for

softball throw. They concluded that their findings supported those from twin studies. Both strength and motor performance variables had a moderate genetic component, but the environment also had a significant role to play, especially as male siblings were found to consistently yield higher correlations than female siblings.

Balance has also been examined and heritability estimates have ranged from .27 (Williams & Gross, 1980) to .86 (Sklad, 1973). Correlations between relatives for psychomotor abilities such as RT, have also yielded inconsistent findings (e.g., Komi, Klissouris & Karvinen, 1973; Vandenberg, 1962).

Conclusions

Although there is substantial evidence for the heredity of many traits and abilities, estimates of heritability have often been highly variable from study to study. As well, genetic theories of talent come under scrutiny when it is observed that exceptional performance can be achieved in the absence of close relatives who possess any skill. For example, Sloboda and Howe (1991) observed that 40% of the most outstanding pupils in a prestigious music school had parents with no musical talent. Indeed, it is possible that even those who do have musically talented parents, could achieve because of special nurturing and early exposure to the domain that interested parents provide. The inconsistency in genetic data for certain traits could be explained by a recent

theory of genetics by Lykken, McGue, Tellegen and Bouchard (1992) called "emergenesis".

In the Minnesota study of twins reared apart, Lykken et al. were surprised to note the number of similarities in idiosyncratic traits/habits between the twins. For example, there were a pair of MZ twins who were habitual gigglers even though they'd been raised separately by undemonstrative parents. DZ twins seldom showed these habitual resemblances. Lykken et al. suggested that the shared traits of MZ twins and the low correlations between DZ twins were the result of a specific configuration of genes. Due to the fact that MZ twins share all their genes they are likely to be highly correlated on most traits (e.g., voice characteristics). However, siblings seldom have similar voice because there is a low probability of inheriting the specific configuration of genes that would indicate heredity of voice. Therefore, their theory offers an explanation for low and inconsistent correlations found between sibling pairs, DZ twins and parent-offspring relationships, even when MZ twin studies yield extremely high correlations.

An example of a trait that could be an emergent property of a configuration of genes is "extraversion". For example, Pederson, Plomin, McClearn and Friberg (1988) found a correlation of .30 for MZ twins reared apart and .54 for those reared together, when DZ twins reared apart only yielded correlations of .04, and .06 for DZ twins reared together.

More noticeably when subjects in the Minnesota study answered questions on occupational and recreational interests 503 pairs of middle-aged MZ twins demonstrated a correlation of .51, however for DZ pairs this correlation was only .14. The MZ twins reared apart showed similar correlations to MZ twins reared together. This finding led Lykken et al. to the conclusion that at least half the stable variance in arts and crafts, as these correlations were stable over a three year retest period, is based on genetic factors but is only slightly familial.

Lykken et al. also claim that their theory can account for genius and exceptional performance. They propose that, "unique configurations of attributes, that cannot be transmitted in half helpings " (p. 1573) lead to exceptional performance. Therefore, there may be many traits or abilities that are actually genetic, but will not be recognised as such unless MZ twins are studied. They conclude that competence in any area is probably a configuration of component traits that one is either born with or not. Plomin and Bergeman (1991) have also claimed that the effect of genetics is actually more widespread than commonly believed. This is due to the genetic influence on traditional environmental measures that has previously gone unconsidered. For example, life event measures have yielded high correlations for MZ twins reared apart (.49) suggesting significant genetic influence due to personality disposition,

for example, especially for events that are designated as controllable.

The important issue when considering genetics is what effect inherent characteristics can have on attainment of high levels of performance. If inherent characteristics are unmodifiable then surely genetic make-up plays a considerable limiting role. Indeed differences between the sexes offer the strongest support for limitation of ability based on genetics and is the reason why sporting events are usually classified by gender.

The role of genetics in the determination of exceptional performance causes one of the most serious problems for Ericsson et al.s' theory. Even interactionists (Plomin, DeFries & Loehlin, 1977) would argue that because the two are so interwined, trying to build a theory solely around practice would be pointless. There are also a number of other problems with Ericsson et al.s' framework that relate back to earlier concerns surrounding the nature-nurture debate, as well as more specific problems with the applicability of the framework to sport.

The most serious problem for any theory that proposes that behaviour is either the result of the environment, or the result of heredity, is that observable behaviour is always a contribution of the two, even prenatally. People can always debate whether a person is predisposed towards a certain behaviour or whether a person engages in a certain activity

because of exposure and encouragement. Klissouras (1972) argued that the question, " 'Is an athlete born or made?' is meaningless...since heredity cannot operate in a vacuum and there must be an appropriate environment where the heredity factor attains full expression." (p. 199).

Conclusions

Although there is substantial suggestive evidence of "innate abilities", there is also considerable evidence detailing the adaptability of a person's general performance capacities as a result of intense practice. Although heritability estimates for certain abilities, such as strength, are quite high, these estimates are for a general population and it may be that unless a person puts in the effort to change or adapt their physiological or cognitive functioning, for example, then they will always perform within certain limits. Recent evidence suggesting that the biological system is actually more adaptable than once believed has begun to emerge. As well, there is significant evidence, especially in sports, that the characteristics that differentiate highly skilled and less skilled athletes are not general abilities, rather domain-specific cognitive skills. This evidence will be reviewed along with age and motivational factors that effect the attainment of expertise.

Support for a Theory of Exceptional Performance Based on "Deliberate Practice"

Cognitive and Perceptual Evidence

Cross-sectional studies of experts have provided considerable evidence that differences in individual performance levels are the result of acquired skills and not innate abilities. A number of studies have shown little or no differences between experts and novices in underlying abilities, on tasks that assess general processing skills, such as SRT, or tasks that measure general perceptual abilities, such as dynamic visual acuity, (Starkes, 1987; Starkes & Deakin, 1984). The primary factors that differentiate various skill levels have been recall of game information and decision accuracy. This superior memory performance has been demonstrated in many different sports including ballet (Starkes, Deakin, Lindley & Crisp, 1987), basketball (Allard et al., 1980), football (Garland & Barry, 1990), snooker (Abernethy et al., 1994) and soccer (Helsen & Starkes, under review). As well, Chase and Ericsson (1981, 1982) have examined many "memory experts" and have concluded that exceptional memory ability is not due to an underlying superior memory capacity, but rather to the acquisition of efficient encoding and retrieval mechanisms acquired through experience within the domain.

For example, Chase and Ericsson (1982) demonstrated that subjects could be taught to improve their memory

performance on the digit span, to equal or better than that reported for "exceptional" subjects. They claim that this ability is not due to a superior basic capacity, as memory experts come to access information from LTM rather than improving their STM capacity (Ericsson, Chase & Faloon, 1980), but rather to memory skills that are acquired, such as chunking, along with efficient encoding and retrieval operations. This claim is substantiated by the fact that superior memory skill shows very little transfer to novel tasks or domains. For example, "SF" (Ericsson & Simon, 1984) used running times to encode digits and therefore could not transfer this strategy to memory for consonents.

The idea that differences in memory performance are due to efficient strategy usage, as opposed to fixed structural differences, has also been substantiated by Brown (1974) who examined causes of poor memory performance in people with mental retardation. Similarly, Bransford, Stein, Vye, Franks, Auble, Mezynski and Perfetto (1982) in a series of studies found that differences between good and poor learners was due to a reluctance of the poor learners to spontaneously go beyond the information given in a text, that is, to elaborate on information, to aid them in recall. However, when these poor-learners received training in elaboration, they were able to considerably improve performance, although generalisability of training was limited.

As early as the late 19th century Bryan and Harter, in their classic investigation of telegraphic skill, discussed the importance of strategy development to the attainment of expertise. They investigated the acquisition of telegraphy skill and noted that the learning curves were characterised by several performance plateaus. Overcoming these plateaus required the acquisition of new strategies which required intense effort and problem solving and indeed not all the telegraphers put in the effort to achieve these "expert" levels. These early findings of Bryan and Harter offer strong support for Ericsson et al.s' theory of "deliberate practice", in that it is the type of practice that is engaged in that is important (i.e., relevant, effortful and not inherently enjoyable), rather than just experience with the domain.

A recent study by Baba (1993) has also provided support for the importance of strategy knowledge rather than general motor ability, in predicting video game performance. Baba devised a series of experiments to determine whether motor performance or strategy knowledge was the greatest predictor of expertise in playing video games. A number of interesting findings emerged. First, movement skill was found to be specific to playing a game subjects were familiar with, 'Lady Bug', along with their familiar joystick. However, even with a different joystick the experts were still twice as good as the novices. In a second study both game knowledge and movement control were compared during acquisition of 'Lady

Bug' skill. There were four groups: the movement group who only practised outside of the game context; the strategy group, who were only given instruction regarding strategy; a group who received both types of instruction; and a control group who received no training at all.

From examination of the learning curves, it was observed that performance scores for all groups were very similar at the start of testing. After a number of hours of practice the group who had received only strategy training (without exposure to the domain), surpassed the movement training only group. In fact by the 10th block of practice subjects who had only received strategy training were performing as well as the group who had received instruction in both movement control and game strategy. It is important to note, however, that differences in movement control only may manifest much later on in development, once the necessary strategies have been acquired. This idea is in accordance with the skill acquisition view that learning undergoes a transition from a declarative mode of control to a procedural one (Anderson, 1982) and also with Ackerman (1988) who has provided evidence that psychomotor abilities account for differences between individuals later in acquisition.

Skilled perception has also been shown to be the result of acquired knowledge and experience within a domain rather than superior "hardware". For example, Helsen and Starkes (under review) have conducted a series of experiments

examining skilled perception in soccer utilising a number of novel techniques. No differences were found between expert and novice soccer players on tasks that measured static acuity, and dynamic visual acuity, however, differences were shown in visual search for domain specific displays, for eye movement fixation, location, and duration. They concluded that due to the expert's knowledge of the game s/he is able to use advance information to anticipate subsequent events. In this experiment it was evidenced by faster initiation of response times for experts when presented with a dynamic situation requiring an appropriate physical response. Similar perceptual advantages for experts have been demonstrated by Abernethy et al. in snooker (1994), Allard et al. (1980) in basketball, Allard and Starkes (1980) in volleyball, Goulet, Bard and Fleury (1989) in tennis, and Lesgold et al (1988) in X-Ray diagnosis.

Recently Adam and Wilberg (1986) and Adam (1987), proposed that the perceptual advantage demonstrated by experts in fast action sports, is due to an underlying ability to rapidly process visual information. They support their theory by showing that the top ranked varsity hockey players, basketball players and down-hill skiers were more accurate at identifying letters displayed at various exposure durations, than the bottom ranked players within the club. However, Starkes, Allard, Lindley and O'Reilly (1994) failed to replicate these findings. In two similar studies, no

significant differences in visual information processing (V.I.P) accuracy were observed between players and non-players and these findings held even when only players were examined, which was comparable to the Adam and Wilberg procedure. For the recall task, no game structure by V.I.P. ability interaction was found, even though recall performance on game slides and diagrams consistently discriminated between players of varying skill levels. Correlations between V.I.P. performance and diagram recall were .28 for players and -0.09 for non-players. Therefore, even if differences are demonstrated between individuals in basic V.I.P ability, this ability is not a necessary or sufficient factor in fast action sports.

It would seem fair to conclude from the evidence above that supposedly stable characteristics, such as memory and perceptual ability, are actually extremely adaptable to the domain where they are used or needed. A short term memory capacity of 7 +/- 2 units (Miller, 1956) does not limit the performance of memory experts who are able to successfully overcome constraints by developing new efficient strategies that can bypass structural limits (Salthouse, 1991). This adaptability of the biological system has recently been shown to be more diverse than originally expected.

Adaptability of Physiological Characteristics

Time and time again studies have demonstrated that there are physiological differences between elite and non-

elite athletes. These differences have been shown for muscle fibre type distribution, the cardiovascular system and lung capacity, among others. Research, however, has been primarily cross-sectional in nature making it extremely difficult to determine whether elite athletes are indeed born with superior physiological systems, that are unmodifiable, or whether these biological factors are adaptable to physical training. Bouchard (1986), after reviewing considerable empirical physiological evidence, concluded that only a moderate genetic component was responsible for differences observed between individuals.

Tesch and Karlsson (1985) have recently demonstrated that the physiological system is not as stable and unmodifiable as once believed. Rather than looking at one specific area of muscle, they examined two separate areas that were trained in one group of athletes and untrained within another. It has frequently been shown that endurance athletes have a higher percentage of slow twitch fibres which are particularly suited for long distance running (see Bouchard, 1986, for a review), however, this result has only been demonstrated when taking biopsies from the leg muscles. Therefore Tesch and Karlsson compared the deltoid (shoulder) muscles and vastus (leg) muscles in kayakers, wrestlers, long distance runners, power lifters and physical education students. They found that the kayakers, wrestlers and lifters had a higher percentage of slow twitch fibres in their

deltoid compared to their vastus muscles, however, the runners had the opposite, a greater percentage of slow twitch fibres in their vastus as compared to their deltoid muscles. Lifters also demonstrated a greater fast twitch area of the vastus than runners. From these findings they concluded that muscle fibre type composition is the result of strenuous exercise of a particular group of muscles, and that heritage of slow twitch fibres cannot alone account for superior performance in endurance runners.

Support for Tesch and Karlsson has come from Müller (1974) and Jaweed, Herbison and Ditunno (1977) who have shown that prolonged exercise of rats leads to a transformation of fast into slow twitch fibres. Salmons and Henriksson (1981) reviewed the area of muscle fibre adaptability and stability and concluded that certain properties of the muscles are resistant to change, but that after prolonged stimulation changes are noted. Indeed, some of the earlier work that has demonstrated the stability of muscle fibre types could be either due to the duration of the exercise or stimulation; that is, it being too short, or because there has been a failure to identify fibres in transformation, now classified as type II C (Jansson, Sjödin & Tesch, 1978).

Prolonged intensive training has also been linked to the size of the heart. Elovainio and Sundberg (1983) followed adolescent elite endurance runners over a five year period and found that although differences in relative heart volume were

not significantly different between endurance runners and normal physically active boys at 14 years, the differences were significant for a number of measurements, including relative heart volume and aerobic power (VO_2max) at 19-20 years of age. Indeed, one of the runners in their study was found to have increased his aerobic power by 29% and it was found that this runner had also covered the greatest training mileage. Hagan, Smith and Gettman (1981) in a regression study designed to predict marathon performance from maximal aerobic power and various training indices, found that although aerobic power was related to marathon performance times, the frequency, intensity and duration of the training program preceding the race accounted for as much of the variation in marathon times as did the physical attributes.

Morganroth and Maron (1977) also demonstrated that the mass of the heart was dependent on the activity engaged in. Similar to Tesch and Karlsson, they showed that athletes who focused on strength, showed a thicker left ventricular wall, which was normal in endurance athletes, but that athletes who focused on endurance showed an increased left ventricular diastolic volume which was normal for wrestlers. Although the possibility of self selection for a specific sport cannot be disregarded, it was found that these characteristics of the heart were outside the normal range of untrained athletes, but that the rest of the cardiac characteristics were actually inside the normal range.

From these physiological studies it is evident that a great deal of intensive training is needed to change biological characteristics to ones more suited to the activity engaged in. It is therefore necessary to review the evidence that individuals who achieve exceptional levels have actually begun training at a particularly young age that would give them the opportunity to adapt their biological apparatus?

Relationship Between Age and Exceptional Performance

The extensive research conducted by Bloom and his associates in various domains of expertise provide us with substantial historical data detailing the ages of initial involvement within various domains, and has led Bloom to propose a 3 stage model detailing the preparation period for attaining exceptional levels of performance. The first stage is extremely important to Ericsson et al.s' framework, as it provides a plausible answer to the important question, what leads to this initial involvement and the continuation of practice for many years? Another important question that needs to be addressed when considering the relationship between age and achievement is why, if performance increases monotonically as a function of age, do performers consistently peak at a certain age within their domain?

Children are continually compared across chronological age for most activities that they undertake. This would include activities such as school work, sport and music. Therefore, if a child gets an early start over his or her

respective age group then s/he will have accumulated more hours of practice at a given age when comparisons are made (e.g., the awarding of academic scholarships). Extra hours of practice that a child engages in before starting systematic practice could lead the coach to attribute extraordinary talent and/or learning ability to the individual, rather than attributing the cause of the performance to a greater amount of experience. Indeed, there is a common bias amongst people to attribute cause internally (Jones & Nisbett, 1972) rather than look around for external causes of behaviour. In the six domains studied by Bloom and his colleagues it was rare that the children were given special instruction because the parents believed that they had some special "talent". Indeed, the fact that the experts had been exposed to the domain early on seemed to account for the child being judged as a fast learner when joining a club/team. An early starting age, however, is not necessarily predictive of expert levels of performance. According to Ericsson et al. initial involvement will need to be maintained for many years for expertise to be achieved, which is not always the case. Indeed, there are many cases of child prodigies who never become adult experts (see for example Bamberger, 1986).

Evidence for this early starting age advantage has been provided by Krogius (1976) in chess, where he found that starting age was correlated (r =.48) with the age of first achievement at international level. Among chess experts, the

age of active participation has consistently been before the age of 10 years (e.g., Krogius, 1976). In the music domain Sosniak (1985) found that for 21 international piano players, the mean age for their first piano lesson was at the tender age of 5.7 years.

In sports there is substantial evidence for early participation. Kalinowski (1985) examined international swimmers and found that they began swimming lessons at 4.5 years and started systematic practice at 7 years. In gymnastics, Kaminski, Mayer and Ruoff (1984, as cited in Ericsson et al., 1993) found a mean starting age of 6.9 years for an adolescent group who had reached regional level, and 9.7 years for the beginning of systematic training. In fact a second group of gymnasts who had reached national level actually started on average 2 years earlier than those of the regional level gymnasts. It is important to bear in mind, however, when considering early involvement in sports, that any type of early physical activity could actually compensate for a lack of early exposure in any one specific sport (Monsaas, 1985). Indeed, certain sports may require a minimal level of strength or height before practice can begin (e.g., rowing or wrestling).

Initial involvement within a domain has been suggested to be primarily a function of the parents, and indeed Bloom (1985), Fowler (1969) and Scheinfeld (1956) have all found that it is usual for at least one of the parents to be

interested in the same or similar activity. Fun and encouragement are often precursors to sustaining of the activity originally, and as suggested by Sloboda et al. (1994) this could be responsible for the development of the high intrinsic motivation that is necessary to continue successfully within the domain. As already noted, if the child is compared to his or her peers, the parents, or indeed the child, may come to believe that s/he has a special aptitude for a specific activity. Kalinowski (1985) noted that in a group of elite swimmers, it was not until quite a while after initial exposure (about 6 years) that the swimmers appeared to be gifted! However, this early enjoyable stage needs to be replaced by the introduction to systematic practice, which according to Ericsson et. al. is no longer enjoyable. Nevertheless systematic practice needs to be sustained for a minimum of 10 years. So, what evidence is there that expertise is not achieved with less than 10 years of experience?

Simon and Chase (1973) observed that nobody had reached the level of a grandmaster chess player, "with less than about a decade's intense preparation with the game" (p. 402). This "10 year rule" has been supported in numerous domains including long-distance running (Wallingford, 1975), mathematics (Gustin, 1985), medical diagnosis (Patel & Groen, 1991), swimming (Kalinowski, 1985) and tennis (Monsaas, 1985). It is not only that expert performers need to spend about 10

years practising, but also the amount of time they spend in practice, according to Ericsson et al. should increase steadily as a function of age. Indeed, when athletes were asked to think back to their weekly involvement in the domain, involvement was reported to increase as the individuals grew older (Kalinowski, 1985; Monsaas, 1985). However, at what point does practice start decreasing and why? Is it that more effort is needed to maintain the current level of performance, due to age related declines, or is it that athletes, or musicians drop out due to conflicts with school, families, injury, or professional careers, as proposed by Sack (1980, as cited in Ericsson, Tesch-Römer & Krampe, 1990)?

Lehman (1953) in a comprehensive book which detailed the relationship between age and achievement using data from the late 19th - early 20th centuries, presented evidence that the greatest achievements in the fields of physical and biological sciences were in the scientists early to mid thirties, this age range was also similar to that of music. In sports these age ranges were much lower, e.g., 22 - 26 years for professional football players, although, the type of sport was important, e.g., 31 - 36 years for peak performance of professional golfers. Lehman suggests that among other things, early peaks could be due to greater responsibilities as a person gets older which inevitably lead to less time to train, a decline in physical vigour, energy and sensory

capacity associated with age, and too great, or too early fame that can lead to complacency.

Ericsson (1990) has more recently reviewed age and peak performance data and research. As Lehman had noted, mean age for peak performance in various sports was demonstrated to be a function of the event and this was supported more recently by Schultz and Curnow (1988) who found that different running distances were associated with different mean ages for Olympic winners, specificaly, 22.85, 24.8 and 27.2 years for 100m, 1,500m and 5,000m races respectively. This age effect was also stable across historical time; that is, the first 9 Olympics compared to the last 8. These findings suggest that there is some maximum of performance level determined by age. Cross-sectional investigations (Letzelter, Jongemann & Freitag, 1986; as cited in Ericsson, 1990), also lend support for this view. They compared best times for master swimmers in the German national swimming championships across age class, ranging from 25 -65 years. In this case a consistent linear decrease with age was found. However, when Letzelter et al. performed a longitudinal analysis, comparing master athletes who had competed in several of the German championships over a 13 year time span, although there were differences in speed between the three age groups, 30 -34, 35 - 39 and 40 - 44 years, no significant decrements in performance were found for individuals across age. This finding suggests that if training is maintained, the decline

in performance is not reliable (see also Stones & Kozma, 1982, who found that cross-sectional studies demonstrate twice as steep a decline in performance as do longitudinal studies.) Indeed, Linford Christie, the British 100 metre sprinter, is still running in 10 seconds or under and he is 35 years old!

Improvements in training and increases in the amount of time spent training would appear to be the primary reason for improvements in performance on specific events. However, Schultz and Curnow (1988) found that the greatest improvement has been demonstrated in the 400m freestyle swimming event, where technical innovations have had the least impact. This would suggest that improvements are primarily due to increased practice hours. Ericsson (1990) also used performance data of master runners, taken from Stones and Kozma (1981), and compared these times to winners of the Olympic games and unofficial World records of 1896. The 50 - 54 year age group matched those times recorded for 6 running events in the Olympics. Even the 65-69 year age group recorded times that were extremely close to these Olympic winners. So decrements in performance with increasing age, can be minimized if there is a continuation of practice activities. Ericsson concluded that declines in peak performance are the result of "pure aging effects on physiological function, decreases in the intensity and extent of training, and possible interaction effects." (p. 191).

Maintaining involvement in a domain for 10 years or more requires considerable motivation on behalf of the performer. This motivation, as indicated above, will be driven by the achievement of goals, but will also start to wane when either these are achieved or when external factors, such as family or career, become more important or begin to demand more time. The following section will address the issue of motivation, in an attempt to determine what drives those few people who reach elite levels of performance.

Motivation as a Moderating Variable to Exceptional Performance

An important constraint influencing duration and intensity of practice is that of motivation. This psychological variable is commonly believed to account for much of the variance between individuals of different skill levels. The fact that motivation is needed to train hard has been frequently demonstrated in both sports and in the work place via implementation of goal setting techniques (Locke, Shaw, Saari & Latham, 1981). Marked improvements for various activities have been demonstrated, even though all goal setting does is produce an increase in duration and intensity of practice or work. Indeed, elite athletes have frequently been shown to spontaneously set their own goals, which could account for the maintenance of their motivation to train. In a summary of the types of goals set by expert performers, Bloom (1985) concluded that in the middle years both long and short term goals are set, but that in the later years these

goals become much more explicit and are planned with the help of the coach.

Goals or incentives are necessary to maintain continued interest in the domain, however the type and length of these not only depend on the stage in the performer's career, but also the domain itself. Csikszentmihalyi, Rathunde and Whalen (1993) conducted a five year longitudinal study on "talented teenagers" within the domains of art, athletics, mathematics, music and science. They claimed that, "...if performance in the domain is not enjoyable in itself, then the field must provide extrinsic rewards to attract gifted young people to it." (p. 110). For example, in the sciences long term career prospects and financial rewards are more likely to be attained by the majority of talented individuals rather than in athletics, where very few receive the recognition and subsequent financial gain that can accompany an elite sportsperson. However, sport offers immediate feedback regarding performance, and it may be that it is this short term intrinsic motivation that sustains the interest of so many for a relatively short period of time, but leads to very few actually continuing until expert levels are achieved. Indeed, it is possible that only those who have the goal-directedness in athletics or the arts, that is long term goals, will be the ones to continue within the domain and succeed. Csikszentmihalyi et al. report the case of 'Ron' the

saxophonist who was extremely committed to music. In an interview, Ron made the following claim:

> All my life I've always set goals. I mean one goal after the next, after the next...And I just work and work and work. I like that. It makes me feel good when I can reach goals, but now they're getting bigger and bigger...My whole life is goals." (p. 236).

Whether this motivation or desire is externally driven by career goals for example, or some dispositional quality of an individual is another important consideration. It may be that one needs to possess a certain combination of personality traits to become an expert in any domain and therefore the identification of these characteristics is necessary.

Kalinowski (1985), who interviewed expert swimmers and their parents, found that the parents frequently described their successful children as independent, determined and competitive. These characteristics were also commonly reported as defining characteristics of other elite athletes, e.g., Monsaas (1985) in tennis. Nearly all the tennis players believed that their personal qualities were more important than their physical attributes. Silva, Schultz, Haslam, Martin and Murray (1985) investigated top level wrestlers to determine what characteristics differentiated the qualifiers at Olympic trials from the non-qualifiers. The non-qualifiers were found to score more highly than the qualifiers for all measures of anxiety, and lower for emotional stability. The qualifiers demonstrated a positive precompetitive affect as measured by tension, depression, confusion and guilt. As this

was a multidimensional study physiological characteristics were also compared between the two groups. However, for physiological characteristics the two groups were very similar, although the qualifiers did demonstrate significantly higher ventilation scores. In accord with previous research, simple reaction time, choice reaction time and dynamic balance failed to discriminate between the wrestlers.

Csikszentmihalyi et al. also found a great deal of similarity in the personalities of their "talented teenagers". Using the Jackson's Personality Research Form (PRF) to compare the personalities of the talented teens to average adolescents, they found that the talented teens scored high in achievement, were intellectually curious, high in perseverance, dominance and exhibition. They were also extremely sensitive to criticism and the females were noted to score highly in androgenous traits, such as determination, and low in typically feminine ones such as orderliness. However, these personality traits had a low correlation with indices of commitment, suggesting that there may be other variables, rather than an individual's personality that are important for continued involvement in the domain. In fact, Csikszentmihalyi et al. identified one construct that correlated with commitment and that was whether an individual reported having a "flow" experience. "Flow" was defined as an experience whereby, "your concentration is so intense, your attention so undivided and wrapped up in what you are doing

that you sometimes become unaware of things that you normally notice." (p. 145).

This finding stresses the importance of intrinsic motivation as being a primary variable in sustaining interest within a chosen domain, especially as "flow" was also a better predictor of commitment than both academic potential and material support. However, even though all the talented individuals reported intrinsic reasons as being the primary reason for engagement in their area, it was the artists, athletes and musicians who identified their talent with "flow" at more than twice the rate of the science and math students.

Another important finding to emerge from Csikszentmihalyi et al.s' research was the fact that the talented children reported spending more time alone than the average children (5 hour/week more). Csikszentmihalyi and Larson (1984) report that being alone was not usually judged as an enjoyable experience, so that a high degree of motivation may have been necessary to do this. Indeed, Csikszentmihalyi et al. (1993) later suggest that "gifted" young children might give up not because they lack the cognitive capacity to process the relevant information, but because they cannot stand working alone." (p. 108). Concentration was also found to be a significant discriminatory quality between the two groups in that the talented teens reported higher levels of concentration in classwork, study, reading, sports and games. However, for

less demanding activities concentration was reported to be really low. The importance of concentration was not surprising given that the "flow" experience was defined as a period of intense concentration.

When considering motivational factors that are responsible for effortful and sustained practice in a domain, it is important to consider the self beliefs of participants, as these may differentiate the experts from the average performers and the individuals who drop-out. Dweck (1986) and Vispoel and Austin (1993) have found that self beliefs are more predictive of future performance in the class-room than IQ. In sports as well, self efficacy beliefs have frequently been shown to be highly related to good performance (e.g., Mahoney & Avener, 1977). Poppleton and Salmoni (1991) conducted a multidimensional investigation of competitive swimmers to determine the characteristics that were predictive of swimming performance. Along with increased shoulder and ankle flexibility, which were likely to be a result of domain specific training, perceived athletic and swim competence measures were found to be the most consistent predictors of performance times across swim strokes. However, it is important to bear in mind that perceptions of competence and efficacy are highly dependent on past performance records and experiences.

Self beliefs may also be important during the initial stages of exposure to a domain, whereby if a child or their

parents believe that certain traits are inborn, such as musical ability or sports performance, they may then lack the necessary commitment to practice, with their belief acting as a self-fulfilling prophecy. Self beliefs are just one of reasons that an individual may not stay committed to an activity for a long period of time, but there are many other factors that are responsible for what has been termed the "drop-out" phenomenon and these must be investigated if a fuller understanding of motivation is to be gained.

The Drop-out phenomenon

When considering the motivational factors that sustain the interest and commitment of athletes over many years, one must also examine the reasons underlying withdrawal from a sport. If withdrawal is a result of low performance, then this has important implications for cross-sectional studies where only those athletes that have continued within the domain are compared. Indeed, Sapp and Haubenstricker (1978, as cited in Burton & Martens, 1986) claimed that more than 1/3rd of the 20,000,000 youth sport participants in the USA drop out of sport each year.

Lindner, Caine and Johns (1991) in a 3 year longitudinal investigation attempted to identify those factors that would predict withdrawal from female competitive gymnastics. Physical (e.g., height and weight), and performance characteristics were examined (e.g., flexibility, endurance and balance) as well as social and psychological

factors. It was found that those who dropped out of gymnastics, were generally taller and heavier, with greater general flexibility, but less gymnastic-specific flexibility, suggesting that the "persisters" spend more time in domain-specific practice as compared to those who drop-out. The authors concluded that age played a significant role in attrition; that is, with increasing age there was a greater chance of withdrawal, possibly due to other interests that become more desirable as an individual grows up. Contrary to expectations the drop-outs scored higher on motor performance variables such as strength, endurance, power and speed and generally responded positively about their perceived competence, therefore withdrawal predictions based on competence (e.g., Weiss, 1986) were discounted.

Burton and Martens (1986) also examined the reasons for withdrawal from sport. Specifically they compared the explanations derived from Nicholls' (1984) motivational model, that individuals drop-out of sport because the activity threatens their perception of ability, to traditional explanations of withdrawal based on conflict of interest, which was previously believed to be the primary variable in sport attrition (e.g., Gould, Feltz, Horn & Weiss, 1981; Robinson & Carron, 1982).

A comprehensive investigation was undertaken of young wrestlers in the USA who were either still wrestling for a club team, or who had voluntarily withdrawn from wrestling in

the previous year, as well as responses from their parents and coaches. Perceived ability was found to be only moderately related to a wrestler's decision to quit the sport. However, coaches rated this as a very important reason, which could be reflective of the attributional biases of actors and observers (Jones & Nisbett, 1972), whereby the observers (coaches) are more likely to attribute the cause of drop-out to internal factors such as ability, rather than external reasons, and vice versa for the wrestlers. Surprisingly, sustaining an injury or facing conflicts with required activities were rated as generally unimportant, suggesting that psychological variables such as strong motivation to succeed may be one of the most predictive variables for continuance in a sport. Indeed, all the groups of respondents, that is the persisters, the drop-outs, their parents and coaches, believed that the reason for drop-out from wrestling was simply due to a loss of motivation. However, it was also found that persisters reported significantly higher levels of perceived ability, and won significantly more matches in the previous season compared to the drop-outs. So, although these data initially suggest that social conflicts or a lack of motivation lead to attrition, there is also support for Nicholl's theory that athletes drop-out as the sport "no longer allows them to infer high ability" (p. 194). These seemingly paradoxical findings are suggested by the authors as due to a number of possibilities. It may be that the wrestlers consciously

attribute decisions to drop-out to external reasons, so that perceived ability is enhanced, or it may be that these decision processes are subconscious, so that even though ability factors are important, the wrestlers are not consciously aware of this.

These findings on drop-out in sport present mixed data concerning the reasons underlying withdrawal. Obviously motivational factors are important for the maintenance of practice within a domain, but these factors could be mediated by performance variables as well as by social conflicts. Further investigation is therefore needed to determine the reasons underlying attrition, with specific emphasis on subjective and objective performance measures, so that the role of psychological and possible physical limits can be further delineated.

Conclusions

From the literature reviewed above there is a multitude of direct and indirect support for Ericsson et al.s' theory that expertise is the result of hours of "deliberate practice". Indeed, it has never been shown that there are "gifted" individuals who can progress in a skill/domain quite effortlessly. For example, Hayes (1981) evaluated 76 major composers and hardly any had produced major works before 10 years of intense practice.

The above evidence highlights how apparent biological constraints can be sufficiently overcome by many hours of

intense practice and that differences in ability cannot account for a significant proportion of the variance between individuals of different skill levels. Limitations that an individual will face will be due to time, finances and motivation. These findings on the adaptability of the physiological system, the importance of domain-specific cognitive skills in characterising expert performers, and the important role of motivational variables in sustaining interest and practice for many years has lead Ericsson et al. to develop a comprehensive framework to examine the acquisition of expertise.

The Development of Expertise as the Result of Hours of "Deliberate Practice": The Theoretical Framework.

The question Ericsson et al. set out to answer was whether practice and experience necessarily lead to expert performance and whether there are any necessary minimal biological attributes. They have distinguished between four types of domain related activities; work, play, observing others and "deliberate practice". "Deliberate practice" involves activities selected primarily to attain and improve certain skills and current performance levels. For example, participating in competitions, would be viewed as work, as it requires a "best" performance, is constrained by time, and often is performed for some external reward. "Deliberate practice" on the other hand does not necessarily require best performance, nor is it necessarily constrained with regard to

hours spent in the activity (although there are obvious limitations, especially in sports where too much practice can lead to injury or burnout, and equipment time and practice partners may be limited).

Play is different from "deliberate practice" and work in that there are no explicit goals and play is inherently enjoyable. Within this framework Ericsson et al. claim that "deliberate practice" is not inherently enjoyable and requires much effort with the motivation to practice being purely because practice improves performance. Ericsson et al. (1993) propose that, "the level of performance an individual attains is directly related to the amount of deliberate practice" (p.370). They believe this relationship to be monotonic with the basic assumption being that, "the amount of time an individual is engaged in deliberate practice activities will be monotonically related to that individual's acquired performance." (p.368)

"Deliberate practice" involves the negotiation of many constraints, namely resource, motivational and effort constraints. Time and energy are required to circumvent the resource constraint, as well as having the available facilities and finances. This is where the family plays an extremely important role as the parents have to sacrifice much of their time and money to provide the optimal training conditions for their children. The importance of parental support was stressed by Bloom (1985), and also by

Csikszentmihalyi et al. (1993). The "talented teens" investigated by Csikszentmihalyi et al were more likely to perceive their families as adaptable to changing circumstance as well as relatively high in cohesiveness, supportive and challenging compared to average adolescents.

The motivational constraint needs to be negotiated if an individual hopes to attain expert levels. This is particularly difficult given that "deliberate practice" activities are not deemed to be inherently enjoyable. The motivation to practice and succeed needs to be strong enough that other more attractive activities, such as leisure time, will have to be sacrificed in order to have the time to practice. As well the effort that is needed to engage in "deliberate practice", which is particulary pertinent to physical activity, needs to be maintained for long periods of time, without sustaining an injury, or reaching exhaustion, fatigue, or burn-out.

Ericsson et al. make a number of explicit predictions regarding the developmental history of the expert performer, the current levels and habits of practice and the experts' evaluations regarding the role and nature of "deliberate practice". First, they claim that the past amount of "deliberate practice" is directly related to an individual's current performance, specifically that expert performance is not reached with less than 10 years of "deliberate practice". Secondly they claim that the highest improvement of

performance, which will indirectly be the highest attained performance, will be associated with the largest weekly amounts of "deliberate practice". They propose that daily periods of "deliberate practice" will be limited with rest periods in between. Finally they predict that experts' evaluations of "deliberate practice" will be high with regard to relevance of the activity to improving performance, high in terms of effort required and low with regard to inherent enjoyment.

Empirical Tests in the Music Domain

A common belief among musicians and non-musicians is that musical talent is a natural ability that a child is born with, which will determine the attainment of exceptional performance. Therefore, musical expertise provides the authors with a challenging area of study. The subjects for the first study were violin students at the Music Academy of West Berlin. Two groups of 10 violinists, from within the same department, were identified by their musical professors as the "best" and "good" groups. A third group was studying to be music "teachers", where lower admission standards were permissable. Ten middle-aged violinists in internationally renowned orchestras were also studied.

Biographical information was gathered via interviews and subjects were asked to estimate how many hours per week they had practised alone with the violin for each year since starting. They were given two activity taxonomies, detailing

everyday activities and musical activities and asked to rate each activity on three dimensions of relevance to improving performance, effort required to perform the activity, and enjoyment. In the second part of the study subjects were asked to keep a diary of all their activities for the upcoming week, and then to code each activity according to the taxonomy.

A number of interesting findings emerged. First, the biographic histories of the subjects were very similar with a mean starting age of 7.9 years, and the beginning of lessons at 8 years. By the age of 23 years all subjects had spent at least ten years practising. Therefore experience within the domain would be judged by an observer to be similar without a close inspection of the type and amount of practice.

There were no differences between groups when comparing ratings for the activities, however, when the ratings were combined, practice alone was given the highest relevance rating. Of the everyday activities only sleep was found to be more relevant than the grand mean for all the activities. Only 2 out of the 8 activities rated as highly relevant were rated as more enjoyable than the overall mean. These were listening to music and group performance. Six out of the 8 activities judged to be highly relevant were also judged to require more effort than average.

Current levels of activities were examined via diary records. Although the two best groups did not differ from

each other in terms of number of hours spent practising alone (M = 24.3 hour/week), they did differ from the group of "teachers", (M = 9.3hour/week). It was found that the two best groups preferred to practice alone for two hours before lunch, which was not evidenced by the "teachers". Duration and distribution of sleep was also examined and it was noted that the two best groups averaged 60 hours of sleep/week whereas the "teachers" only averaged 54.6 hours. This difference was attributed in part to napping time during the afternoon.

When leisure time was observed there was a significant difference between the two best groups with the "good" violinists spending more time in leisure (M = 4.7hour/day) than the "best" violinists, (M = 3.5hour/day). However, there was no significant difference between the "teachers" and the average of the two best groups.

LeBlanc and Salmela (1987) have also compared the amount of time spent in leisure activities for gymnasts who had been followed over seven years. Those who were still in the sport, "persisters", were compared to those who had dropped out. They found that, "the time devoted to leisure could best differentiate the persistent from the drop-out gymnasts, with the former spending more time in this area than the latter" (p. 199). Even though all Ericsson et al.s' subjects were "persisters", the finding that leisure and rest time are important to the training regime was supported. It

appears, however, that some leisure time needs to be sacrificed in order to spend time practising. Indeed, Ericsson et al. found that for all the young violinists there was a negative correlation between time spent in leisure activities and music related activities.

When the retrospective estimates of "deliberate practice" were examined correlations between both actual time spent in an activity and estimated times for a typical week were quite high. However, there was a tendency for the experts to overestimate. The authors suggested this was an indication of practice levels aspired to, as opposed to attained. For all groups practice time alone increased monotonically from the start of practice until 20 years of age. From these retrospective estimates accumulated practice was calculated. To avoid a bias toward the music academy this measure was calculated for the groups up until 18 years of age. The "best" group averaged 7,401 hours, which was significantly different from the "good" group, who averaged 5,301 hours. The average of the two best groups was reliably different from that of the "teachers", who averaged 3,420 hours. The difference was not significantly different for the "best" and the middle-aged group, as would be predicted from the framework.

Ericsson et al. were also able to generalize their findings to piano experts. When a group of expert pianists were compared to an amateur group, diary records demonstrated

that the experts practised alone for 26.71 hour/week, whereas, the amateur group only averaged 1.88 hours of practice alone. Sleep and leisure time however, did not differ for the experts and the novices. Subjects in this study were also compared on a couple of general tasks unrelated to music, a choice reaction time task and a digit-symbol substitution test. No differences between the two groups were demonstrated on these tasks. This finding is in agreement with numerous other studies that have examined "hardware" components of motor experts (e.g., Abernethy et al., 1994; Baba, 1993; Helsen & Starkes, under review; Starkes, 1987; Starkes & Deakin, 1984).

On tasks related to the skill of piano playing differences were observed. For simple finger tapping, experts were found to be faster than amateurs with regard to their interstroke interval. For a more complex hand coordination task the experts again outperformed the novices. To examine the predictiveness of their theory Ericsson et al. decided to see whether they could predict performance on the skill related tasks from hours of practice, just as well as predictions based on subjects' level of expertise. A regression analysis revealed that accumulated hours of practice alone did indeed predict performance on the skill related tasks just as well as differences in expertise level, which indicated that even something as simple as tapping speed is acquired rather than inherited.

Sport Specific Issues and Concerns

It is clear from Ericsson et al.s' studies that there is considerable support in the music domain to substantiate a theory of expertise based on "deliberate practice". The starting age is consistently young, both current and past levels of practice differentiate skill levels and accumulated practice is a significant predictor of performance in skill related tasks.

However, there are problems with the specifics of Ericsson et al.s' framework when it is applied to sport. For example, in sports there are some activities that individuals engage in that are designed to maintain, rather than improve performance (e.g., flexibility training in gymnastics or wrestling). Also controlling diet is an important part of the training regime in sports and is an activity designed to improve performance but questions then arise as to whether this would be considered "deliberate practice" according to Ericsson et al.s' framework, especially as most athletes would rate it very low in inherent enjoyment! This problem would also relate to the calculation of accumulated practice hours and the question of whether they actually are accumulated "practice" hours or "maintenance" hours?

In the music domain, training alone has been found to be the most important activity, but in some sports training "alone" is extremely hard, due to the nature of the sport (e.g., wrestling where one requires a partner, and obviously

for team sports). Therefore, one would predict that training alone would not be the most important factor for improving performance, rather training with others would be, which could also lead to increased enjoyment for the activity (see Csikszentmihalyi et al., 1993). Indeed team sports are often engaged in for this very reason, and the psychological makeup of a team player may be very different from an individual athlete.

Related to the above point are the number of resource constraints that an athlete may face compared to a musician. Not only is there the necessity to train with a team or a partner in many sports, but sports often require specialized equipment and facilities such as an ice rink or a training gymnasium. Resource constraints may have serious impact on the time an individual can spend in specific types of practice.

Another problem with the model is that competition hours are not considered as important to the framework, yet it is commonly observed that those who are more experienced with the event, are better able to cope and yield their best performances. For example, an individual who has wrestled in four tournaments compared to an individual who is just entering his first, even though their hours of practice may be equivalent, the more experienced wrestler would be expected to yield the better performance. Indeed, the theory of context dependent learning (Godden & Baddeley, 1975) would predict

that those who have learned, or had more experience performing under specific circumstances, will perform well under similar situations. However, it may be that competition hours are indeed important and necessary, but that alone, hours spent competing do not differentiate the expert performers from those who are less skilled. Although this may be the case for musicians, competitions may play a more significant role in sports. It may be that in sport the number of competitions entered is also a significant predictor of expertise.

In sport, practice activities are heavily dependent on the time of year as many sports are seasonal in nature. Therefore, when individuals are asked to think of a "typical week" this could be heavily dependent on the time of year or stage in the competitive schedule. Due to this inconsistency in the training regime throughout the year, when accumulated practice hours are calculated they could be seriously overestimated if they are calculated based on estimates for a typical week in mid season.

"Deliberate Practice" in Wrestling

The purpose of the following study was to test Ericsson et al.s' theory in sport and examine the amount of "deliberate practice" wrestlers of different levels of performance engage in. Wrestlers were chosen for study as they provide a comparable group to Ericsson et al.s' musicians, in that wrestling is also an individual event. For the first part of the study retrospective data concerning

past practice levels over the wrestlers' careers were collected for four groups of wrestlers; 2 groups of current wrestlers, both international and club, and 2 groups of retired wrestlers, both international and provincial level(or below). The wrestlers were required to estimate the amount of time they had spent in practice alone, practice with others, wrestling related activities and everyday activities. Within each of these categories there were specific activities encompassed by each, and subjects were asked to rate these activities for relevance to improving performance, effort and concentration required to perform the activity, and inherent enjoyment. Subjects were also required to provide biographic information relating to their competitive success, career goals, the age of beginning wrestling and systematic practice.

In the second part of the study, current levels of practice were compared for current international and club wrestlers, who were asked to keep an extensive diary of all the activities they had engaged in during a one week period. Before completing this diary they were asked to estimate the time spent in various activities during their most recent, typical week.

Study 1

Method

Participants

Four groups of male amateur wrestlers participated voluntarily in the first study. Two groups were current wrestlers and 2 groups had retired from competitive wrestling. The current wrestlers consisted of 15 members of the Canadian National wrestling team and 9 who were members of the McMaster University Wrestling Club, which is considered one of the best in Canada. The retired wrestlers were 9 ex-international wrestlers (7 Canadian, 1 Russian and 1 Italian). There was also a group of 8 wrestlers who wrestled at or below provincial level (5 Canadian, 1 S.Korean and 2 USA/Canada). The current ages of the four groups in the study were as follows; international-current (IC) 24.1 $\pm$ 1.9year, club-current (CC) 24.8 $\pm$ 3.2year, international-retired (IR) 38.2 $\pm$ 5.1year and club-retired (CR) 35.9 $\pm$ 8.5year.

Procedure

All subjects received a questionnaire asking them to reflect on their careers and recall their past amounts of practice and other wrestling related and everyday activities. It was explained to the subjects either verbally or by mail that,

> The study involves looking at retrospective reports of practice levels over the span of one's career, to test a theory of expertise proposed by Ericsson, Krampe and Tesch-Römer (1993) that expertise is the direct result of a long period of "deliberate practice" and not innate talent.

The Questionnaire. The first section of the questionnaire asked for biographic information concerning the age when practice was first initiated, the highest level attained in wrestling, success in competitions, the number of coaches and the country of training. There then followed 4 sections that required subjects to think back to the amount of time they had spent practising for wrestling: alone, with others, in practice related activities and in everyday activities during a typical week. They were required to estimate the number of hours since beginning wrestling to the present time (for current wrestlers) or until retirement from competitive wrestling, for every three years only. A list of activities then followed which included typical activities encompassed by each of the four sections. These activities were determined after consultation with expert wrestlers. For each activity the wrestlers were asked to rate the activity on four dimensions using a scale from 0-10, where 0 was low and 10 was high. They were asked to rate for; relevance to improving wrestling performance, effort required to perform the activity, how enjoyable the actual activity was and how much concentration was required to perform the activity. When these sections were completed there followed several questions regarding the number of competitions

subjects had entered/year and the number of clinics they had attended or given at the start of wrestling and for the present time (or at the peak of their career for the retired wrestlers). They were also asked to think back across their wrestling careers and detail the types of goals they had set at the start and for the present time (or peak). Subjects were also required to recall the duration of their off-season for every three year period throughout their career (see Appendix A for copy of questionnaire).

Results

Biographic Information

All groups began wrestling at a similar age ($\underline{M}$ = 13.2 $\pm$ 0.6year) and engaged in systematic practice on average 1 year after starting ($\underline{M}$ = 14.08 $\pm$ 0.6year). Both the retired groups reported reaching their "peak" in wrestling at similar times, ($\underline{M}$ = 25.1 $\pm$ 0.7year), none of the age differences were significant ($\underline{p}$>.05). For the retired athletes, the average time difference from when they began wrestling to when their career peaked was 11.4 $\pm$ 1.2year. There was also a high degree of consistency with regard to the number of coaches the four groups had ($\underline{M}$ = 4.6 $\pm$ 0.3). The international and club wrestlers appeared to participate in about the same number of competitions when they began wrestling (Int. $\underline{M}$ = 8.1; Club $\underline{M}$ = 8.8), but the number of competitions entered at the present time (or peak) increased for the international wrestlers, but not for the club (Int. $\underline{M}$ = 13.7; Club $\underline{M}$ =

8.5). This difference was analyzed in a 2 skill level (Int., Club) by 2 time period (Start, Present (Peak)), mixed ANOVA. Although there were no main effects of skill ($F(1,40) = 1.81$, ns: Int. $M = 11.08$, Club $M = 8.69$) or time period ($F(1,40) = 3.07$, ns: Start $M = 8.38$, Present(Peak) $M = 11.4$), the interaction between skill and time period approached conventional levels of significance, $F(1,40) = 3.71$, $p = .061$. There were no significant differences between the international and club wrestlers for the number of matches wrestled, clinics given or attended (see Appendix G, Tables 2a-2j).

As well as providing information concerning the number of competitions the wrestlers had entered they were also required to give more specific information regarding their success at competitions, so that the validity of the subjects' groupings could be ascertained. It was difficult, however, to perform any analyses on these data as subjects differed immensely with regard to the detail they gave, however, from the information that was given, their "best" results at competitions could generally be ascertained. There appeared to be a lot of variation between the subjects, both between and within the groups as to their success. For the international-current wrestlers their best results ranged from being 9th in the Olympic games to placing 3rd, 4th or 5th in the World championships, to coming 2nd or third at senior national competitions. The international-retired

wrestlers had an impressive list of accolades, with Olympic team membership being the most prestigious and common to 8 out of the 10 wrestlers in this group; one first place, one 4th, one 8th and one 9th. The current-club level wrestlers had mainly achieved success at the Canadian universities' national championships (CIAUs) or provincial championships, 2 of the 9 wrestlers had won the CIAUs. Similar successes to the club-current wrestlers were also observed for the club-retired athletes (see Appendix B).

Retrospective Estimates Over The Wrestlers' Careers

The data were analyzed as a function of the number of years the wrestlers had been involved in wrestling practice with others, practice alone and wrestling related activities. In order to maximize the number of subjects analyzed (since half the wrestlers were still mid-career) the hours/week that athletes practised at the start of their career, and at three and six years into their careers only were examined. Since no effect of "cohort"(current and retired) was demonstrated for hour/week for any type of wrestling related activity this variable was collapsed across. The data were then analyzed using a 2 skill (Int., Club) by 3 number of years (Start, 3year, 6year) mixed ANOVA. When all types of wrestling activities were summed, although there was no effect of skill ($F(1,40) = 1.821$, ns), there was a significant skill by number of years interaction, $F(2,80) = 3.492$; $p<.05$. Tukey HSD, $p<.05$ post hoc analyses of this interaction revealed

that at some point after 3 years into the wrestlers' careers, the international wrestlers began to differ with regard to the amount of time they were spending in all wrestling activities (at 6 years: Int. M = 38.7hour/week, Club M = 28.4hour/week). Figure 1 presents these data. Although at the start of practice both groups spent the same amount of time in wrestling activities, within three years the international group devoted more time to practice (Int. M = 26.2hour/week; Club M = 20.9hour/week).

Insert Figure 1 about here

To determine specifically what activity accounted for the differences between the groups, the data were analyzed separately for practice alone and practice with others. Practice alone yielded no significant differences between the groups, nor did time spent in practice related activities (see Appendix G, Tables 3a-3l), therefore practice time with others was found to be the differentiating factor between the groups. A main effect of group was demonstrated, $F(1,40) = 3.919$, $p<.05$, as well as a group by number of years interaction, $F(2,80) = 4.837$; $p<.01$. Post hoc analyses yielded significant differences between the groups at 6 years into their career (Int. M = 16.1hour/week; Club M = 11.6hour/week).

To provide a comparison to Ericsson et al.s' data, accumulated amount of practice with others was examined, as a function of the number of years involved in wrestling. For each subject, line graphs were used to estimate the number of hours subjects had spent in the intervening years (see Appendix C, for example), so that data were available from the start of practice, for every year until the present (or end of career). To calculate cumulative practice hours, the number of hours/week were multiplied by 52 for each year, and then reported hours spent in off-season (see Appendix G, Table 4) were subtracted from these estimates. Multivariate analyses of variance were performed on the data over the first 6 years using a fixed effects model with 2 between factors; skill (Int., Club) and cohort (Current, Retired). As before, there was no effect of "cohort", Rao's $\underline{R}$ (7,32) = 1.87, $\underline{p}$ = .11. There was, however, a significant difference between the practice times reported for the international and club groups, Rao's $\underline{R}$ (7,32) = 2.34, $\underline{p}<.05$ (Int. $\underline{M}$ = 1252.74; Club $\underline{M}$ = 1067.08). No interaction was observed, Rao's $\underline{R}$ (7,32) = 1.25, $\underline{p}$ = .31. The data pertaining to these analyses are illustrated in Figure 2.

Insert Figure 2 about here

When univariate analyses were conducted as post hoc tests on the effect of skill, a significant difference

between the 2 groups first emerged after 5 years into their wrestling career, $F(1,38) = 5.379$, $p<.05$. At 6 years into their wrestling career the international group had accumulated 2767 hours of practice with others, compared to 2099 hours accumulated by the club wrestlers. Multivariate analyses for practice alone, practice related activities or for all practice activities summed together did not yield any significant differences (see Appendix G, Tables 5e-g).

The data were also explored as a function of age, however, due to the fact that subjects began wrestling at different times and half were midway through their career, an analysis across ages, from 13-23 years was impossible. Therefore separate one way ANOVAs were conducted, to compare the differences between the skill levels at various ages. A significant difference between the groups for practice with others was first demonstrated at 20 years of age, $F(1,38) = 4.916$, $p<.05$. By this age the international group had accumulated an average of 3226.4 hours of practice, over 1000 more hours of practice with others than the club athletes, $M = 2220.5$. At 23 year of age, 10 years after beginning wrestling, the international group had accumulated an average of 5881.9 hours, compared to the club wrestlers, who had accumulated a mean of 3571.1 hours.

There were no significant differences between the international and club wrestlers for any of the everyday activities. For hours spent sleeping, a significant decrease

in the amount of time spent sleeping across the wrestlers' careers was noted, but this effect was common for all groups, $F(2,78) = 11.87$, $p<.001$ (Start $M = 57.38$; 3 years $M = 53.78$; 6 years $M = 53.09$). Time spent in active leisure was also found to decrease as the wrestlers progressed through their careers, $F(2,80) = 4.14$, $p<.05$ (Start $M = 11.63$; 3 years $M = 10.45$; 6 years $M = 8.97$).

Evaluations of Wrestling Related and Everyday Activities

Subjects were required to rate each activity within each of the following four sections; practice activities alone, practice activities with others, activities related to wrestling and everyday activities. All were rated on a scale from 0-10, for relevance, effort, concentration and enjoyment. The ratings for each activity were analyzed separately to determine if the international and club wrestlers were rating differentially, which could account for their allocation of time to various activities (see Appendix G, Tables 8a-c).

There were no significant differences between the skill levels for practice with others, however, the club athletes rated "training alone with the coach" significantly higher for all the evaluations ($F(1,34) = 4.217$, $p<.05$: Int. $M = 7.36$, Club $M = 8.34$) than the international wrestlers, as well as "watching themselves on video" ($F(1,32) = 4.952$, $p<.05$: Int. $M = 5.97$, Club $M = 7.22$). No interactions were found between skill level and the ratings given.

Therefore, due to the high similarity in the way the activities were rated by the wrestlers, further analyses were collapsed across the groups. For each rating, a mean was calculated and compared to the overall mean for all the activities using a *t*-test. Statistical significance was determined using adjusted alpha levels according to Bonferroni's method (that is alpha was divided by 26, i.e., the number of activities). Table 1 displays the means for the various sections collapsed across groups.

Insert Table 1 about here

Within the table, those activities that were rated significantly higher than the overall mean are denoted with an 'H', and those that were lower than the overall mean are denoted with an 'L'. As can be seen within the practice with others section, mat work received high ratings for relevance and effort, but also significantly high ratings for enjoyment and concentration. Running with others was also given a high rating for effort. For practice activities alone, working with the coach received a high rating for relevance, enjoyment and concentration while weight training and running were both rated high for relevance and effort. Within the wrestling related activities, mental rehearsal received a significantly high rating for both relevance and concentration. Sleep was rated as highly relevant and

enjoyable, yet as expected low in effort and concentration. Both active and non-active leisure received high ratings for enjoyment only.

A Spearman's correlation was used to determine the relationship between the 4 ratings for the wrestling activities. It was found that relevance correlated most highly with concentration, ($\underline{rho}$ = .83, n = 21, $\underline{p}$<.05) then effort ($\underline{rho}$ = .68, n = 21, $\underline{p}$<.05), but also with enjoyment, ($\underline{rho}$ = .59, n = 21, $\underline{p}$<.05).

The wrestlers in this study were also required to provide information regarding the types of career goals they set at the start of their careers and for the present time (or peak). They were asked to think of these goals in terms of length, that is short or long term, as well as specificity.

For the international-current wrestlers, the goals at the start of their careers were relatively short term, relating to High school success; although 11 out of the 15 wrestlers, reported that they soon began to strive for national team membership and international success. The current goals for the international wrestlers were related to being on the Olympic team, or winning an Olympic medal (for 11 of the wrestlers). The club-current wrestlers had similar goals to the international wrestlers at the start of their careers, although none of the club wrestlers reported that they wished to be on the national team, and only 2 mentioned

competing in a national tournament as one of their goals. The international-retired group reported setting similar goals to the international-current at the start of their careers, with half of the group aiming for national team membership and success. The goals set at the peak of their careers were more specific than those at the start, and related to practice, mental training and specific placings in international competitions. Again for the club-retired wrestlers at the start of their careers, the goals they set were generally in terms of High school success, although 2 out of the 8 wrestlers in this group reported that they wanted to wrestle in the Olympics. One of the wrestlers from this group reported that they did not remember setting goals. Another claimed that, "If I'd wanted to make wrestling a focus, I would have set goals in a different way." Another wrote that, "I knew that I was unwilling to make the sacrifices to be a national team member" (for complete description of goals, see Appendix D)

Discussion

The biographic data from the wrestlers supports the data of Ericsson et al. in that all four groups demonstrated similar profiles. However, the wrestlers in this study did not begin wrestling until 13 years of age, much later than the 8 years of age noted for musicians. This is not surprising, however, given that wrestling requires a certain degree of physical maturity, before the activity can be

engaged in with any success and safety. It is possible that the later starting age observed in wrestling may be responsible for the high levels of practice reported at the start of the wrestlers' careers, compared to the musicians. Consistent with previous literature the difference between the starting ages and peaks reported by the retired wrestlers was greater than 10 years. Although the number of matches wrestled, either at the start of wrestling or for the present time (or peak) did not differentiate the skill levels, the number of competitions entered in the current year (or at the peak), did yield considerable differences. Therefore, competition time, may indeed be an important variable in distinguishing between international and club level wrestlers, and should be considered across the entire career span of wrestlers.

The retrospective estimates demonstrated that practice did indeed differentiate wrestlers of different skill levels, from relatively early on in their careers. The amount of practice reported was consistent across the cohort factor, that is no differences were found between the current and retired athletes, which supports the validity of these estimates. The similarities between the current and retired wrestlers estimates also supported the reliability of recall, in spite of the elapsed time for the retired wrestlers. Accumulated practice yielded estimates for the international wrestlers very similar to those of Ericsson et al.s' best

violinists. Ten years after beginning wrestling the wrestlers had accumulated 5865 hours of practice with others compared to 6351 hours of practice alone accumulated by the violinists. This similarity is particularly noteworthy, given that wrestling activities are much more constrained by facility availability, time, and access to sparring partners, than practice alone with the violin. As well, time spent in the off-season was taken into account when the yearly amounts of practice were estimated which would likely lead to a more conservative estimate than Ericsson et al's.

In the examination of the ratings given to various activities it is particularly interesting to note that relevant activities were also judged to be enjoyable. This is in contrast to the definition of "deliberate practice" proposed by Ericsson et al. However, even in Ericsson et al.s' data, although practice alone and with others were not rated significantly higher than the overall mean for enjoyment, the ratings were actually higher than the overall mean. As well, wrestling is an inherently social activity, and competitive and physical in nature, all of which the wrestlers find enjoyable.

Another interesting finding to emerge from the evaluations is the importance of concentration as a separate factor from effort. This appears to be an important distinction when referring to physical activities. It would appear that concentration refers more to the cognitive nature

of the activity as opposed to effort, which refers to the physical nature of the activity. For example, "mental rehearsal" and "working alone with the coach" were rated high for both relevance and concentration, whereas running and weight training were rated significantly higher than the overall mean for effort. This distinction is especially important in light of the finding that relevance correlates most highly with concentration.

Although the retrospective estimates provided information concerning general activities the international wrestlers spend more time doing, such as practising with others, it would also be useful to examine the time allocated to specific activities. That is, what type of practice activity with others is responsible for the differences between the groups. Do the international wrestlers spend more time in activities that they judge to be most relevant, such as sparring, weight training and running? Indeed, it would be interesting to see whether the time spent in specific activities actually changes as the wrestlers progress through their careers. The diary study provided the opportunity to examine more specifically the activities that wrestlers engage in.

Study 2

Method

Participants

Ten members of the Canadian National amateur wrestling team (9 had participated in the first part of the study) and 11 McMaster University Wrestling Club members (4 had taken part in the first part of the study) were compared. All the subjects were male and the average age of the international wrestlers was 25.1 ± 2.4year, the average age of the club wrestlers was 23.09 ± 3.4year. All subjects were paid for their participation in this study.

Procedure

Subjects were first asked to think back to the activities they had engaged in during their most recent, typical week (both wrestling related and everyday), and according to a taxonomy of activities (see Table 2) estimate the number of hours they had spent in each activity. A description of some of the more ambiguous activities accompanied the taxonomy (e.g., fitness training alone was described as an activity performed to maintain or improve level of fitness which could include; cycling, running, jogging, aerobics or swimming).

Insert Table 2 about here

Subjects were then instructed that they would be required to keep a detailed diary for a seven day continuous period (see Appendix E). They were asked to "be as detailed as they saw necessary" and to "be specific as to whether the activity was performed alone or with others", where this was seen to be important. Subjects were asked to "fill out the diary sheet at the end of every day before going to bed, and to be consistent with this procedure." Seven 24 hour diary sheets were provided that were divided into 15 minute sections. An example then followed of how the diary was to be completed. Subjects were also required to provide biographic information, as in study 1, and were required to answer questions regarding their views on "talent". At the end of the seven day period subjects were asked to return their diaries in a sealed envelope, and were asked to note whether they thought this was a typical week for them or not.

As a second part to the study, 3 "expert" coaches were asked to rank the international wrestlers on a scale from 1-10, so that the predictiveness of practice could be examined in relation to this measure of skill. The coaches were familiar with the international wrestlers, and had been involved in coaching at an international level. They were asked to consider the skill, current performance and how well the wrestler would perform in a major international tournament, when assigning the rank. They were told that the same rank could not be assigned to more than one wrestler,

and that a rank of "1" was the highest performance rank that could be given, and "10" was the lowest. When the coaches differed in their ranks a mean rank was calculated and these mean ranks were then ordered from 1-10. Only the club team coach ranked the club wrestlers[1]

Results

Biographic Information

As in study 1, all subjects began practising at a similar age (13.3 ± 2.3year) and engaged in systematic practice on average one year later (Int. M = 14.0year; Club M = 15.5year). Both groups reported that wrestling became more full time at about 17 years, and both wrestled with a similar number of coaches (Int. M =4.6; Club M = 3.6). As before, the number of competitions subjects had entered was analyzed in a 2 skill (Int., Club) by 2 time period (Start, Now) mixed ANOVA. There were no significant differences between the 2 groups with regards to the number of competitions they entered either when they began wrestling or in their most recent year. There were also no differences for the number of matches they had wrestled.

The wrestlers were also asked questions pertaining to their personal views of themselves as talented individuals (see Appendix F). In reply to the question, "How good were

[1] When the rankings were assigned only 10 club wrestlers had completed the diaries.

you when you first began wrestling?" the international wrestlers reported more initial success than the club wrestlers. Only one of the international wrestlers reported that he was average, even though he still reported being successful, whereas half of the club wrestlers reported being of average ability, or below. Both groups tended to attribute any success to physical characteristics such as size and athleticism. When they were asked, "When if ever did you first appear to have a natural talent for this event?", only 1 international wrestler and 1 club wrestler reported having a "natural talent" on first beginning. One international wrestler replied,

> I never thought I had a talent for wrestling. I was always good at sports already - I like to think I got to where I am with hard work. Hard work is what separates those that are at the top, compared to those who have equal or more talent, but are not as successful.

These replies indicate that the athletes themselves see the importance of experience within a domain, before perception of "talent" can be made. For a sport like wrestling, physical fitness before beginning appears to be an important discriminatory factor as indicated by the number of international wrestlers who made reference to their physical characteristics, such as size or speed, when starting out.

The Diaries

The diaries were analyzed in a similar fashion to Ericsson et al., so that comparisons could be made across

domains. However, the delineation of the activities was decided by the experimenter, not the wrestlers themselves, so that a degree of consistency could be maintained across subjects. Any activity that could be given multiple encodings, was divided equally across the relevant categories. All activities were summed so that comparisons could be made with regard to total time spent in each activity. These totals were then analyzed by a 2 skill level (Int., Club) between subjects ANOVA. As well, relevant activities were analyzed as a function of day and time of day.

For wrestling related activities, the international and the club wrestlers spent the same amount of time/week in these activities, (Int. $\underline{M}$ = 24.88; Club $\underline{M}$ = 24.57). Not surprisingly the wrestling activity that the subjects spent most time doing was engaging in wrestling practice, which was also the activity judged as most relevant to improving performance (Int. $\underline{M}$ = 9.03 $\pm$ 2.3; Club $\underline{M}$ = 9.80 $\pm$ 4.3). Unfortunately, only some of the subjects actually divided up the time in wrestling practice to provide information concerning time spent alone or with others warming up, observing others, listening to the coach, or wrestling on the mats. So for the purpose of analysis wrestling practice was always assumed to be with others.

For the other activities judged to be highly relevant to improving wrestling performance, that is, weights alone,

running alone and mental rehearsal, there were no significant differences between the 2 groups in terms of the amount of time they devoted to these activities. Both groups averaged about 2 hours/week in fitness activities alone (Int. $\underline{M}$ = 2.48 $\pm$ 1.6; Club $\underline{M}$ = 2.08 $\pm$ 1.8) and reported fitness activities with others was considerably less than this (Int. $\underline{M}$ = .55 $\pm$ 0.7; Club $\underline{M}$ = .21 $\pm$ 0.3, for full table see Appendix G, Table 11a).

Time spent travelling was the only activity to significantly differentiate between the two groups, for the everyday activities (see Appendix G, Table 11b). The international wrestlers reported spending a mean of 17.4hour/week travelling compared to 6.25hour/week for the club wrestlers, $\underline{F}(1,19) = 22.11$, $\underline{p}<.001$. The percentage of time each wrestler spent travelling as a function of time of day (weekdays only) was examined. This was calculated for each 2 hour period between 6am - 10pm and analyzed in a 2 skill (Int., Club) by 8 time period (6am - 10pm, 2 hour blocks) mixed ANOVA. A significant effect of group was observed, $\underline{F}(1,19) = 10.94$, $\underline{p}<.01$ (Int. $\underline{M}$ = 12.25%; Club $\underline{M}$ = 4.18%) as well as a main effect for time of day, $\underline{F}(7,133) = 6.62$, $\underline{p}<.001$. When this effect was further analyzed by a Tukey HSD, $\underline{p}<.05$ post hoc test it was found that the wrestlers were travelling most between 2 - 4pm (before training begins, $\underline{M}$ = 17.5%) and 6 - 8pm (when training usually ends, $\underline{M}$ = 15.3%, see Figure 3).

Insert Figure 3 about here

Although the differences were not significant, the international wrestlers were also spending more time at work compared to the club wrestlers, both in wrestling related and unrelated work (Int. $\underline{M}$ = 17.93; Club $\underline{M}$ = 10.18). This could have important implications for scheduling of practice activities for the international wrestlers, especially given the fact that they report spending so much time travelling to training. The majority of the club wrestlers were students, which was reflected in the differences in study time/week, (Int. $\underline{M}$ = 8.1; Club $\underline{M}$ = 19.23) although due to the high variance between subjects this difference was not significant, $\underline{F}(1,19) = 3.25$, $\underline{p} = .09$. So for the club wrestlers facilities necessary to train, such as the wrestling mats and weights were more readily available in the University and residence. Indeed, it was also found that the international wrestlers were actually engaging in fewer practice sessions/week (of any type), compared to the club wrestlers ($\underline{F}(1,19) = 4.93$, $\underline{p}<.05$), Int. $\underline{M}$ = 8.80 $\pm$ 2.0; Club $\underline{M}$ = 11.45 $\pm$ 3.2), but were spending a longer amount of time engaged in the activity ($\underline{F}(1,19) = 5.45$, $\underline{p}<.05$), Int. $\underline{M}$ = 111 $\pm$ 18min; Club $\underline{M}$ = 90.6 $\pm$ 20min. Presumably, if one spends so much time travelling to and from appropriate facilities, one

travels less often and spends more time at the actual practice.

The distribution of various practice activities across the diary week was analyzed in a 2 skill (Int., Club) by 7 day mixed ANOVA. A significant effect of day was found for engaging in practice activities, $F(6,114) = 19.689$, $p<.001$. Post hoc analyses showed a significant decrease for time spent in practice activities during the weekend, compared to the week days (weekdays M = 2.9hour; weekends M = 0.8hour). This main effect of day was primarily due to time spent in actual wrestling practice. Compared to fitness activities alone and with others only wrestling practice yielded a significant effect of day ($F(5,95) = 12.56$, $p<.001$).

Commensurate with the travel times noted above, when the percentage of practice time (all practice activities) was examined as a function of time of day for weekdays only, a significant effect of time of day was found, $F(7,133) = 33.94$, $p<.001$. Post hoc analyses indicated that between 4 and 6pm, 65.52% of the wrestlers' time was spent practising, which was significantly different from all the other times. There was also an elevated amount of practice between 8-10am (21.41%) and 6-8pm (24.73%)(see Figure 4).

Insert Figure 4 about here

No differences were noted for leisure time, either active leisure or non-active leisure, nor did leisure time negatively correlate with the amount of time the athletes were spending in wrestling related activities (r = .29, n=21, ns). However, the reported means for leisure time, for both the international wrestlers and the club wrestlers were very similar to those found by Ericsson et al. for their best violinists, (Int. M = 3.07hour/day; Club M = 3.46hour/day, Best violinists, M = 3.5hour/day). Given that Robinson, Andreyenkov and Patrushev (1988) reported that average 18-29 year olds spend 5.2hour/day in leisure activities, these figures would indicate that the wrestlers were sacrificing their leisure time for wrestling related activities.

Since subjects were required to estimate the amount of time they had been engaging in the wrestling related and everyday activities before completing the diaries, it was possible to examine the validity of these estimates[2] . As well, it was possible to look back at the retrospective estimates given for the wrestlers who were in both Studies 1 and 2 and compare their estimates for the most recent year, with those reported in the diaries.

For practice activities with others the Pearson correlations between a typical week and the diary data were:

---

[2] One of the club wrestlers in the diary study failed to provide estimates of time spent in wrestling and everyday activities during their previous week.

international wrestlers, r = .66, n = 10, p<.05; club wrestlers, r = -.16, n = 10, p>.05. The international wrestlers reported spending 10.88hour engaged in practice activities with others, but estimated that they spent 17.55hour/week, this difference was significant, $F(1,9)$ = 6.83, p<.05. The club wrestlers spent 9.73hour/week in practice with others, but estimated spending 17.05hour/week, this difference was also significant, $F(1,9)$ = 9.98, p<.05 (see Appendix G, Tables 17a-d, for totals). When wrestling related activities were examined more specifically in a 2 skill (Int., Club) by type of estimate (Diary, Recent week) mixed ANOVA, it was found that both groups of subjects overestimated a number of the wrestling related activities including: fitness activities with others ($F(1,18)$ = 11.27, p<.01), Recent M = 3.98; Diary M = .39; amount of time at wrestling practice with others ($F(1,18)$ = 6.80, p<.05), Recent M = 10.78; Diary M = 8.94; and watching wrestling ($F(1,18)$ = 5.04, p<.05), Recent M = 2.43; Diary M = .53. However, there were no significant differences between the recent and the diary week for strength training, professional conversation, fitness alone and diet/weight monitoring. It was also found that the international wrestlers' correlations between their most recent week and the diaries were generally much higher than those for the club wrestlers. For example, the following correlations were found for; strength training alone, Int. r =.96; Club r = -.19, strength training with

others, Int. r = .98; Club r = .06 and attending wrestling practice, Int. r = .76; Club r = .15. These high correlations noted for the international wrestlers suggest that their routine is more consistent and systematic than that noted for the club athletes, and that training has become a habitual activity. Since they overestimate, this could be more an indication of how much time they aspire to train, rather than actually attain. This was also suggested by Ericsson et al. with reference to their musicians.

The everyday activities also yielded some very high correlations between the diary week and a typical week, especially for sleep (r = .67, n=20, p<.01), study (r = .91, n=20, p<.01), travel (r = .82, n=20, p<.01) and work (r = .84, n=20, p<.01) and there were very few significant differences noted between the estimates and the diaries. For example, the international wrestlers estimated that they spent an average of 17.20hour/week in non-active leisure which was comparable to the diary mean of 17.78hour/week. For both groups the estimates of travel time for a typical week were lower than those reported in the diaries. However, the international wrestlers estimates for time spent travelling were significantly greater than the club wrestlers; F(1,18) = 10.055, p<.01: Int. M = 8.53(3.6), Club M = 3.55(3.4). It would seem therefore, that the time spent in wrestling activities during this week may not have been very typical for the wrestlers, given that they were accurate

at predicting the time spent in everyday activities. However, only 2 of the international wrestlers reported that the week when they completed the diary was not typical, compared to 4 of the club wrestlers and 1 who abstained from answering.

When the diary data and retrospective estimates from study 1 were correlated for the international wrestlers, no significant correlations were found for practice with others (r = -.03, n=9, ns) or practice alone (r = .31, n=9, ns). However, for the international wrestlers, the diary means and the retrospective estimates were very similar for practice time with others, (Retro. M = 15.22; Diary M = 11.36). As well, the retrospective estimates for the international wrestlers correlated with the estimates for a typical week; practice alone, r = .73, n=9, $p<.05$, practice with others, r = .50, n=9, ns. It is important to note, however, that the retrospective estimates were finished in July and August, whereas the diaries were not completed until February or March of the following year, which could reflect seasonal variations in practice activities.

A stringent test of Ericsson et al.s' theory would be to determine whether time spent in "deliberate practice" activities could actually differentiate the wrestlers within a group. That is, can we predict the rank assigned to the wrestlers by expert coaches, from any of our measures of deliberate practice? To answer this question separate

regression analyses were performed on the ranks, for time spent in practice with others and practice alone.

For time spent in practice with others during the diary week, the r^2 values were: Int. r^2 = .012, df=9, ns; Club r^2 = .286, df=9, ns, although the regression equation showed that this was in the opposite direction to that predicted (y=-.444x + 10.236hour). Surprisingly practice time alone explained 37% of the variance in ranks for the club wrestlers (r^2 = .374, df=9, ns), but again r^2 was negligible for the international wrestlers (r^2 = .004, df=9, ns). As accumulated practice time with others was available from the retrospective estimates for nine of the international wrestlers, a regression analysis was also performed on these data. Accumulated practice with others accounted for only 11% of the variance in ranks (r^2 = .113, df=9, ns), although again the regression equation showed a very slight negative relationship (y=-.0004x + 7.823hour).

Discussion

Although the diary data failed to yield any significant differences between the international and club wrestlers for wrestling related activities, a number of important findings emerged. First, it was apparent from the everyday activities that the international wrestlers had to be particularly careful allocating time to practice activities. Given that they spent a long time travelling to practice, compared to the club wrestlers, it seems wise that

when they did practice, they spent longer doing so. The importance of circumventing resource constraints was stressed by Ericsson et al. (1993) as particularly necessary to achieve and maintain expert levels of performance. The international wrestlers seem to have found a way of doing this even though many of them work full-time. The fact that the international wrestlers travel so far to train reflects the necessity to practice at a place where the best sparring partners are, as well as the best coaches.

The lack of predictiveness for practice time with others was discouraging, although this failure could be due to the subjectivity of the rankings, or the difficulty in trying to predict within group differences. That is, rather than using subjective rankings it may have been preferable to use point rankings, objectively determined from tournament success. However, three respected "expert" coaches ranked the international wrestlers and they were provided with a very brief summary of each wrestler's success in competitions to aid in their judgement.

The lack of significance may also be attributed to the difficulty in trying to predict rank within a skill group, rather than between groups. Due to the lack of variability between subjects within the same skill group, attempting to account for variance becomes a problem. This is supported by the higher $\underline{r}^2$ values noted for the club wrestlers, who are a less homogenous group than the

international wrestlers. However, it was time spent in practice activities alone that accounted for 37% of the variance between ranks for the club wrestlers. This predictability of practice time alone for the club wrestlers may be reflective of the relative importance of different types of training, depending on the level of expertise. In the diaries none of the wrestlers reported spending any time practising wrestling moves alone, so therefore all the activities that the wrestlers engaged in alone, during this week, were either fitness, strength or flexibility related.

It may be that for the club wrestlers, spending the time in individual practice activities, such as running and weight training, are extremely important, as physical strength and fitness may play a more significant role at the lower levels of competition. That is, fitness and strength characteristics may be more likely to discriminate between 2 club level wrestlers in the same weight class. However, at the international level one would expect the wrestlers to be equal (within a weight class) for physical fitness, so that technique, that is acquired through training on the mats, may be the most important attribute for winning matches. "Practice alone" for the international wrestlers may be more a question of "maintenance", and although they engage in as much practice alone as the club athletes, this type of practice does not differentiate wrestlers at the same level of competition.

General Discussion

The retrospective estimates of study 1, provide quite substantial support for a theory of expertise based on "deliberate practice". Practice time with others consistently differentiated the international from the club wrestlers, both for hours/week spent in practice and accumulated practice hours, regardless of whether the wrestlers were current or retired. However, Ericsson et al.s' definition of "deliberate practice" requires further clarification given that the wrestlers report that practice is enjoyable, and that this factor correlates highly with relevance of the activity to improving performance. It may be that "deliberate practice" is specific to an actual activity, in that activities performed with others may be rated as more enjoyable than those alone. However, in a recent study of elite figure skaters, Hayes and Deakin (under review), also found that activities rated high for relevance were also rated significantly high for enjoyment, even though figure skating is an individual activity. It may be then that "deliberate practice" is specific to a domain, such as sport. This is further supported by the fact that concentration and effort are rated differentially depending on the activity, with effort relating to the physical work required and concentration referring to the cognitive nature of the activity, for both the wrestling data and the skating data. In physical domains this distinction appears to be an

important one, with activities that are both high in concentration and effort being considered as "deliberate practice". Csikszentimahalyi et al. (1993) also found that high levels of concentration were demonstrated by the "talented teens" when engaging in activities related to their areas of expertise.

In an attempt to discover factors responsible for the motivation to practice, the types of career goals that the wrestlers had set at the start of their careers and currently (or at their peak) were investigated in the first study. Although it was difficult to draw any firm conclusions from these reports, generally the international wrestlers had higher aspirations than the club athletes. The current/peak goals of the wrestlers were generally more specific than the ones set at the start of their careers, especially for the international wrestlers. This supports Bloom's (1985) conclusions, that the goals set by expert performers in their later years are more explicit, than those set early on in their careers. It is not clear, therefore, whether initial goals have an impact on the attainment of expertise, it may just be that they are necessary to maintain practice and improve performance, once a high level is achieved.

Although the retrospective estimates of time spent in practice with others demonstrated encouraging support for Ericsson et al.s' theory, the diary data from study 2 failed to yield any significant differences between the skill levels

for time spent in practice activities. This was surprising, given the findings from the first study, therefore reasons for this discrepancy were explored.

The club wrestlers in the diary study were not all the same ones that completed the retrospective questionnaires, and on examination of their ages they were observed to be considerably younger than the international wrestlers. Given that the international wrestlers were generally older than the club wrestlers it may be that some of them were past their peak in wrestling when the diaries were completed, and therefore adjusted their practice levels accordingly. Alternatively, as the club wrestlers were still quite young, it may be that some of them could still achieve international status, especially as McMaster wrestling club in considered one of the best in Canada. Indeed, it may be that actual wrestling level aspired to, which one would expect to be highly related to the actual level reached, is also an important indicator of the amount of time subjects spend in practice. Ideally the same subjects would have been assessed in both the retrospective and the diary study, however, this was not possible due to the fact that some of the club wrestlers had retired or left the university, and were replaced by new wrestlers in the 2nd part of the study.

Although at first inspection this result appears to contradict the findings from Ericsson et al.s' research with musicians, Ericsson et al. also failed to find differences

between their two best groups of violinists for the diary study, even though accumulated practice hours alone differentiated the two best groups. It may be that the club wrestlers in this study were more comparable to Ericsson et al.s' "good" group of violinists, rather than the "teachers" or the amateur pianists, especially as the club wrestlers were wrestling in National competitions, only one level below the international wrestlers.

Although the international and club wrestlers did not differ with respect to total time spent in practice activities in the diary study, they did differ with regards to the duration of time spent in practice, and time spent travelling to and from practice. The increased time spent in travel for the international wrestlers reflected the necessity to train at a club where the best sparring partners were available as well as the best coaches. Indeed, the ultimate "deliberate practice" for wrestlers is sparring with a partner who is of at least equal size and ranking. It follows from these increased travel times for the international wrestlers that when they do practice they spend a significant period of time engaged in it.

The diaries also yielded some unexpected findings when predictiveness of practice was examined with respect to skill rankings assigned to the international and club wrestlers. Neither practice time with others, or alone, predicted differences in skill ranking for the international

wrestlers. It was suggested that this may be due to the homogeneity of the international group, or to the subjective nature of the rankings. For the club wrestlers, practice time alone was the only significant predictor of rank. As discussed, strength and physical fitness may be discriminatory characteristics for club level wrestlers, but technical-tactical actions, acquired through mat work, may be the factor that differentiates wrestlers at international levels. Indeed the findings from the retrospective reports, that practice time with others is the only variable to yield significant differences between the international and club wrestlers, further supports this claim.

Subjects in the diary study were also asked questions about their views on "talent", and how successful they were at the start of their wrestling careers. Although only one of the international wrestlers perceived himself as having a "natural talent", paradoxically, all the international wrestlers reported that they were successful from the start and tended to attribute this success to physical characteristics, such as athleticism. This discrepancy could be due to the international wrestlers engaging in other physical activities before starting wrestling, that could have given them initial advantages when beginning wrestling. This may then lead to an attribution for performance based on prior experience, rather than innate talent. It would be interesting to see how the international wrestlers actually

define "talent", as it would seem that physical characteristics may not be encompassed by their definition.

Recommendations for future study of "deliberate practice"

In the future, rather than examining practice time alone and with others, the issue should be one of isolating practice hours from those activities that are engaged in to "maintain" physical levels of strength and fitness. Whether one runs or cycles alone is not the important issue, given that a partner can have little or no impact on the intensity or engagement of these activities. Rather, whether one engages in practice to improve their wrestling technique, as opposed to maintain or increase their strength, is the critical question. Although the two are highly related, that is with greater strength and flexibility more moves are possible, a more elaborate definition of "deliberate practice" will be gained by the delineation of the two.

Related to this issue it is the necessary to examine the microstructure of practice, to ascertain specifically what it is the wrestlers are spending their time doing when they are at wrestling practice or training. Do the international wrestlers engage in more wrestling-specific activities, than the club wrestlers, such as bench-press to increase upper body strength? At wrestling practice do the international wrestlers spend more time scrimmaging rather than watching others or working on fitness?

It is recommended that future investigations employ more objective measures of performance skill, such as a wrestler's point ranking, to examine whether accumulated practice hours can be used to predict these objective rankings. Given that an adequate range between the point rankings of the wrestlers was examined and a relationship was found, one would then be able to estimate how many hours of practice an individual needs to engage in to progress at each stage in wrestling. This avenue of research is currently being explored.

With regards to support for a theory of expertise based solely on "deliberate practice" the answer is still unclear. Since the study was cross-sectional, the subjects were already experts and therefore conclusions cannot be made about the causative nature of practice. Indeed, it may be that those who are more "talented" practice more. However, the retrospective estimates failed to yield differences in the amount of practice until a number of years into the subjects' careers. Ideally a longitudinal study should be conducted so that data regarding practice can be collected on a yearly basis, and a causal role could be established. However, this would require an extremely large sample pool, with the possibility that none of the subjects ever become experts, due to the many constraints and distractions that face athletes along their career paths.

A prospective study would also permit an investigation of physical/physiological characteristics that could provide an advantage for certain athletes. In future studies objective records of initial performance should be examined to see whether those who became international wrestlers demonstrated initial advantages, before they had time to accumulate sufficient practice hours. If this is indeed the case then factors other than "deliberate practice" need to be considered, such as physiological capacity or the type of physical activities engaged in before wrestling was initiated.

The type and role of practice is obviously an extremely important area of study, and one that has been frequently overlooked with regards to the attainment of expertise. Future studies are needed to determine what causes individuals to spend such a considerable amount of time practising if it isn't the belief that they possess an innate talent. Therefore, motivational factors need to be investigated across all phases of skill acquisition. Although, career goals were investigated in the present study, a more in-depth investigation is recommended for future studies, specifically focussing on the long-term effects of specific types of goals. This is especially important given that the short-term utility of goals has frequently been demonstrated in prospective studies (e.g. Locke et al., 1981).

To validate Ericsson et al.s' findings from pianists, it is suggested that the predictiveness of accumulated practice hours is also examined in relation to traditional cognitive tasks, that have consistently discriminated athletes of different expertise levels (e.g., Allard et al., 1980; Starkes, 1987). For example, accuracy of recall of sport specific information, could be used as a measure of skill as in previous studies, and the predictiveness of accumulated practice hours could be examined in relation to individual differences in recall accuracy.

Further testing of Ericsson et al.s' model across other types of sport is necessary to substantiate the findings from these studies. Both individual and team sports should be investigated within this current framework, as well as "simple" sports, such as sprinting, that is traditionally believed to be a function of innate physical ability, compared to sports that are considered to be primarily a result of training, such as bowling or snooker.

So to achieve a high level in wrestling a number of factors would seem to be necessary. Firstly, there is considerable support for the necessity of early exposure to the domain so that a sufficient number of practice hours with others can be accumulated. However, starting late, does not mean that expertise cannot be achieved, but rather the late starter will need to spend considerably more time in relevant, effortful practice per week to catch up with those

who have had advantages of an early starting age. In domains, other than wrestling, the average age of those who are successful may be considerably older, and therefore a late starting age would not be a disadvantage.

When engaging in practice activities a high degree of concentration should be maintained as well as considerable physical effort. Mat work is the most important and relevant activity and a significant proportion of time at wrestling practice should be spent in this type of activity. Fitness and strength training are both extremely important, especially if the activity is specific to wrestling. To become an international wrestler, a great deal of time must be spent overcoming constraints to practice, such as travelling a significant distance to practice and maintaining motivation at the expense of leisure time, for example.

It is evident from these studies that continued effortful engagement in "deliberate practice" activities are necessary to achieve expertise, however, the question of whether it is sufficient still remains unanswered.

References

Abernethy, B., Neal, R.J., & Koning, P. (1994). Visual-perceptual and cognitive differences between expert, intermediate, and novice snooker players. Applied Cognitive Psychology,8, 185 - 211.

Ackerman, P.L. (1988). Determinants of individual differences during skill acquisition: Cognitive abilities and information processing. Journal of Experimental Psychology: General,117(3), 288 - 318.

Adam, J.J., & Wilberg, R.B. (1992). Individual differences in visual information processing rate and the prediction of performance differences in team sports: A preliminary investigation. Journal of Sports Sciences,10, 261 - 273.

Allard,F., & Graham, S., & Paarsalu, M.E. (1980). Perception in sport: Basketball. Journal of Sport Psychology,12, 14-21.

Allard, F., & Starkes, J.L. (1980). Perception in sport: Volleyball. Journal of Sport Psychology,2, 22 - 33.

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

Baba, D.M. (1993). Determinents of video game performance. In J.L. Starkes & F. Allard (Eds.), Cognitive issues in motor expertise (pp. 57-74). Amsterdam: North Holland.

Bamberger, J. (1986). Cognitive issues in the development of musically gifted children. In R.J. Sternberg, & J.E. Davidson (Eds.), Conceptions of giftedness (pp.388-416). Cambridge, England: C.U.P.

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

Bouchard, C. (1986). Genetics of aerobic power and capacity. In R.M. Malina, & C. Bouchard (Eds.), Sport and human genetics (PP.59-88). Champaign, IL: Human Kinetics Publishers.

Bouchard, T.J., Jr. (1984). Twins reared together and apart: What they tell us about human diversity. In S.W. Fox (Ed.), Individuality and determinism: Chemical and biological bases (pp. 147 - 178). New York: Plenum Press.

Brace, D.K. (1927). Measuring motor ability. New York: A.S. Barnes.

Bransford, J.D., Stein, B.S., Vye, N.J., Franks, J.J., Auble, P.M., Mezynski, K.J., & Perfetto, G.A. (1982). Differences in approaches to learning: An overview. Journal of Experimental Psychology: General,11(4), 390 - 398.

Brown, A.L. (1974). The role of strategic behaviour in retardate memory. In N.R. Ellis (Ed.), International review of research in mental retardation,Vol 7, NY: Academic Press.

Bryan, W.L., & Harter, N. (1897). Studies in the physiology and psychology of the telegraphic language. Psycholgical Review,6, 345 - 375.

Burton, D., & Martens, R. (1986). Pinned by their own goals: An exploratory investigation into why kids drop out of wrestling. Journal of Sport Psychology,8, 183 - 197.

Charness, N. (1976). Memory for chess positions: Resistance to interference. Journal of Experimental Psychology: Human Learning and Memory,2, 641 - 653.

Chase, W.G., & Ericsson, K.A., (1981). Skilled memory. In J.R. Anderson (Ed.), Cognitive skills and their acquisition. (pp. 141 - 189). Hillsdale, NJ: Erlbaum.

Chase, W.G., & Ericsson, K.A., (1982). Skill and working memory. In G.H. Bower (Ed.), The psychology of learning and motivation (Vol.16, pp.1-58). San Diego, CA: Academic Press.

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.

Cohen, A.J., & Baird, K. (1990). Acquisition of absolute pitch: The question of critical periods. Psychomusicology,9, 31 - 37.

Csikszentimahalyi, M., & Larson, R. (1984). Being adolescent. New York: Basic.

Csikszentimahalyi, M., Rathunde, K. & Whalen, S. (1993). Talented teenagers: The roots of success and failure. NY: C.U.P.

deGroot, A.D. (1965). Thought and choice in chess. The Hague: Mouton.

Dweck, C.S. (1986). Motivational processes affecting learning. American Psychologist,41, 1040 - 1048.

Elovianio, R., & Sundberg, S. (1983). A five year follow-up study on cardio-respiratory function in adolescent elite endurance runners. Acta Paediatrica Scandanavia,72, 357-360.

Engostrom, L.M., & Fischbein, S. (1977). Physical capacity in twins. Acta Geneticae Medicae et Gemellologiae,26, 159-165.

Ericsson, K.A. (1990). Peak performance and age: An examination of peak performance in sports. In P.B. Baltes, & M.M. Baltes (Eds.), Successful aging: perspectives from the behavioral sciences. (pp.164-195). Cambridge, England: C.U.P.

Ericsson, K.A., Chase, W.G., & Faloon (1980). Acquisition of a memory skill. Science,208, 1181 - 1182.

Ericsson, K.A., & Faivre ,I.A. (1988). What's exceptional about exceptional about exceptional abilities? In I.K. Obler, & D. Fein (Eds.), The exceptional brain: Neuropsychology of talent and special abilities (pp.436-473). New York: Guildford Press.

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

Ericsson, K.A., & Simon, H.A. (1984). Protocol analysis: Verbal reports as data. Cambridge, MA: MIT Press.

Ericsson, K.A., Tesch-Römer, C., & Krampe, R.T. (1990). The role of practice and motivation in the acquisition of expert-level performance in real life: An empirical evaluation of a theoretical framework. In J.A. Howe (Ed.), Encouraging the development of exceptional abilities and talents.(pp.109-130). Leicester: The British Psychological Society.

Fitts, P. (1964). Perceptual-motor skill learning. In A.W. Melton (Ed.), Categories of human learning. (pp. 243 - 285). San Diego, CA: Academic Press.

Fitts, P., & Posner, M.I. (1967). Human Performance. Monterey, CA: Brooks/Cole.

Fleishman, E.A. (1960). Abilities at different stages of practice in rotary pursuit performance. Journal of Experimental Psychology,60, 162 - 172.

Fleishman, E.A. (1964). The structure and measurement of physical fitness. Englewood Cliffs, N.J.: Prentice-Hall.

Fleishman, E.A., (1966). Human abilities and the acquisition of skill. In E.A. Bilodeau (Ed.), Acquisition of skill. New York: Academic Press.

Fleishman, E.A. (1972). On the relation between abilities, learning, and human performance. American Psychologist,27, 1017 - 1032.

Fleishman, E.A., & Hempel, W.E., Jr. (1955). The relation between abilities and improvements with practice in a visual discrimination reaction task. Journal of Experimental Psychology,49, 301 - 316.

Fleishman, E.A., & Hempel, W.E. (1956). Factorial analysis of complex psychomotor performance and related skills. Journal of Applied Psychology,40,96 - 104.

Fleishman, E.A., & Rich, S. (1963). Role of kinesthetic and spatial-visual abilities in perceptual-motor learning. Journal of Experimental Psychology,66, 6 - 11.

Fleishman, E.A., & Quaintance, M.K. (1984). Taxonomies of human performance. Orlando, FL: Academic Press.

Fowler, W. (1969). The effect of early stimulation: The problem of focus in developmental stimulation. Merrill-Palmer Quarterly,15, 157 - 170.

Galton, F. (1875). The history of twins as a criterion of the relative powers of nature and nurture. Fraser's Magazine,92, 566 - 576.

Galton, F. (1892). Heredity genius (2nd ed.). London: Macmillan.

Gardner, H. (1983). Frames of mind. The theory of multiple intelligences. NY: Basic Books.

Gardner, H. (1993a). Creating minds. NY: Basic Books.

Gardner, H. (1993b). Multiple intelligences: The theory in practice. NY: Basic Books.

Garland, D.J., & Barry, J.R. (1990). Sport expertise: The cognitive advantage. Perceptual and Motor Skills,70, 1299 - 1314.

Gross, E., Griessel, D.C., & Stull, G.A. (1956). Relationship between two motor educability tests, a strength test and wrestling ability after eight weeks of instruction. Research Quarterly,27, 395 - 402.

Godden, D., & Baddeley, A.D. (1975). Context-dependent memory in two natural environments: On land and under water. British Journal of Psychology,66, 325 - 331.

Gould, D., Feltz, D., Horn, T., & Weiss, M. (1981). Reasons for attrition in competitive youth swimming. Journal of Sport Behavior,5, 155 - 165.

Goulet, C., Bard, C., & Fleury, M. (1989). Expertise differences in preparing to return a tennis serve: A visual information processing approach. Journal of Sport and Exercise Psychology,11, 382 - 398.

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.

Hamel, P., Simoneau, J-A., Lortie, G., Boulay, M.R., & Bouchard, C. (1986). Heredity and muscle adaptation to endurance training. Medicine and Science in Sports and Exercise,18(6), 690 - 696.

Hayes, A., Deakin, J. (1995). Creating elite athletes in figure skating: fact or fiction. Manuscript submitted for publication.

Hayes, J.R. (1981). The complete problem solver. Philadelphia: Franklin Institute Press.

Helsen, W., & Starkes, J.L. (1995). A multidimensional approach to skilled perception and performance in sport. Manuscript submitted for publication.

Henry, F.M. (1961). Reaction time-movement time correlations. Perceptual and Motor Skills,12, 63 - 66.

Hill,A.L. (1978). Savants: Mentally retarded individuals with special skills. In N.R. Ellis (Ed.), International review of research in mental retardation, Vol 9. New York: Academic Press.

Howe, M.J.A. (1989). The strange achievements of idiots savants. In A.M. Colman & J.G. Beaumont (Eds.), Psychology survey 7. Leicester: B.P.S. and Routledge Ltd.

Ishidaya, Y. (1957). Sportfahigkeit der Zwillinge. Acta Geneticae Medicae et Gemellologiae,6, 312 - 326.

Ivry, R. & Keele, S.W. (1989). Timing function of the cerebellum. Journal of Cognitive Neuroscience,1, 136 - 152.

Jansson, E., Sjödin, B., & Tesch, P. (1978). Changes in muscle fibre type distribution in man after physical training. A sign of fibre type transformation? Acta Physiologiae Scandanvia,104, 235 - 237.

Jaweed, M.M., Herbison, G.J., & Ditunno, J.F. (1977). Myosin ATPase activity after strenghtening exercise. Journal of Anatomy,124, 371 - 381.

Jones, E.E., & Nisbett, R.E. (1972). The actor and the observer: Divergent perceptions of the causes of behavior. In E.E. Jones, D.E. Kanouse, H.H., Kelley, R.E., Nisbett, S., Valins, & B. Weiner (Eds.), Attribution: Perceiving the causes of behavior (pp.79-94). Morristown, NJ: General Learning Press.

Jones, S.K. (1993). A modular approach to individual differences in skill and coordination. In J.L. Starkes & F. Allard (Eds.), Cognitive issues in motor expertise. (pp.273 - 294). Amsterdam: North Holland.

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 Books.

Kaminski, G., Mayer, R., & Ruoff, B.A. (1984). Kinder und Jungendliche im Leistungssport. Schrdorf, Federal Republic of germany: Hoffman.

Keele,S.W., Cohen, A., & Ivry, R. (1990). Motor programs: Concepts and issues. In M. Jeannorod (Ed.), Attention and performance XIII: Motor representation and control. (pp.77-110). L.E.A.

Keele, S.W., Ivry, R.I., & Pokorny, R.A. (1987). Force control and its relation to timing. Journal of Motor Behavior,19(1), 96 - 114.

Keele, S.W., Pokorny, R.A., Corcos, D.M., & Ivry, R. (1985). Do perception and motor production share common timing mechanisms: A correlational analysis. Acta Psychologica,60, 173 - 191.

Klissouras, V. (1972). Genetic limit of functional adaptability. Internationale Zeitschrift fur Angewandte Physiologie,30, 85 - 94.

Klissouras, V. (1973). Erblichkeit und training-studien mit zwillingen. Leitungsport,5, 357 - 368.

Klissouras, V. (1976). Canadian Journal of Applied Sport Sciences, 1, 195 - 200.

Komi, P.V., Klissouras, V., & Karvinen, E. (1973). Genetic variation in neuromuscular performance. Internationale Zeitschrift fur Angewandte Physiologie,31, 289 - 304.

Kovar, R. (1974). Prispevek ke studiu geneticke podminosti lidske motoriky. Doctoral dissertaion, Charles University.

Kovar, R. (1981). Human variation in motor abilities and its genetic analysis. Prague: Charles University.

Krogius, N. (1976). Psychology in chess. New York: RHM Press.

LeBlanc, M, & Salmela, J.H. (1987). Longitudinal time management patterns of elite persistent and dropout gymnasts. In J.H. Salmela, & T.B. Hoshizaki (Eds.), World identification systems for gymnastic talent (pp.94-112). Montreal: Sport Psyche Editions.

Lehman, H.C. (1953). Age and achievement. Princeton, NJ: Princeton University Press.

Lesgold, A., Rubinson, H., Feltovich, P., Glaser, R., Klopfer, D., & Wang, Y. (1988). Expertise in a complex skill: Diagnosing x-Ray pictures. In M.Chi, R.Glaser, & M.J. Farr (Eds.), The nature of expertise (pp.311 - 342). Hillsdale, NJ: Erlbaum.

Letzelter, M., Jungermann, C., & Freitag, W. (1986). Scwimmleistungen im Alter. Zeitschrift für Gerontologie,19, 389 - 395.

Levitin, D. (in press). Absolute representation in auditory memory: evidence from the production of learned memories. Perception and Psychophysics.

Lindner, K.J., Caine, D.J., & Johns, D.P. (1991). Withdrawal predictors among physical and performance characteristics of female competitive gymnasts. Journal of Sports Sciences,9, 259 - 272.

Locke, E.A., Shaw, K.N., Saari, L.M., & Latham, G.P. (1981). Goal setting and task performance: 1969 - 1980. Psychological Bulletin,90, 125 - 152.

Lundy-Ekman, L., Ivry, R., Keele, S., & Woollacott, M. (1991). Timing and force control deficits in clumsy children. Journal of Cognitve Neuroscience.,3, 367 - 376.

Lykken, D.T., McGue, M., Tellegen, A., & Bouchard, T.J. (1992). Emergenesis: Genetic traits that may not run in families. American Psychologist,47, 1565 - 1577.

Mahoney, M.J., & Avener, M. (1977). Psychology of the elite athlete: An exploratory study. Cognitive Therapy and Research,1, 135 - 141.

Malina, R.M. (1984). Genetics of motor development and performance. In R.M. Malina & C. Bouchard (Eds.), Sport and human genetics, Vol. 4. Champaign, IL: Human Kinetics Publishers, Inc.

Miller, G.A. (1956). The magical number seven, plus or minus two. Psychological Review,63, 81 - 97.

Monotoye, N.J., Metzner, H.L., & Keller, J.K. (1975). Familial aggregation of strength and heart rate response to exercise. Human Biology,47, 17 - 36.

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 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 Publishers.

Malina, R.M., & Mueller, (1981). Genetic and environmental influences on the strength and motor performance of Philadelphia school children. Human Biology,53(2), 163 - 179.

Marisi, D.Q. (1977). Genetic and extragenetic variance in motor performance. Acta Geneticae Medicae et Gemellologiae,26,197 - 204.

Morganroth, J., & Maron, B.J. (1977). The athlete's heart syndrome: A new perspective. Annals of the New York Academy of Sciences,301, 931 - 941.

Müller, W.(1974). Temporal progress of muscle adaptation to endurance training in hind limb muscles of young rats. A histochemical and morphometrical study. Cell Tissue Research,156, 61 - 88.

Nicholls, J.G. (1984). Striving to demonstrate and develop ability: A theory of achievement motivation. In J.G. Nicholls (Ed.), The development of achievement motivation. Greenwich, CT: JAI Press.

Patel, V.L., & Groen, G.J. (1991). The general and specific nature of medical expertise: A critical look. In K.A. Ericsson & J. Smith (Eds.), Toward a general theory of expertise: Prospects and limits (pp. 93 -125). Cambridge, England: C.U.P.

Pederson, N.L., Plomin, R., McClearn, G.E., & Friberg, L. (1988). Neuroticism, extraversion, and related traits in adult twins reared apart and reared together. Journal of Personality and Social Psychology,55, 950 -957.

Plomin, R. (1986). Development, genetics and psychology. Hillsdale, NJ: Erlbaum.

Plomin, R. (1988). The nature and nurture of cognitive abilities. In R.J. Sternberg, Advance in the psychology of human intelligence, Vol 4 (pp. 1 - 33). Hillsdale, N.J.: LEA

Plomin, R., & Bergeman, C.S. (1991). The nature of nurture: Genetic influences on "environmental" measures. Behavior and Brain Sciences,14, 373 - 427.

Plomin, R., DeFries, J.C., & McClearn, G.E. (1980). Behavioral genetics: A primer. San Francisco: Freeman.

Plomin, R., DeFries, J.C., & Loehlin, J.C. (1977). Genotype environment interaction and correlation in the analysis of human behavior. Psychological Bulletin,84, 309 - 322.

Poppleton, W.L., & Salmoni, A.W. (1991). Talent identification in swimming. Journal of Human Movement Studies,20, 85 - 100.

Prud'Homme, D.C., Bouchard, C., LeBlanc, F., & Landry, F. (1984). Reliability of assessment of ventilatory thresholds. medicine and Science in Sports and Exercise,16(5), 489 - 493.

Robinson, J.P., Andreyenkov, V.G., & Patrushev, V.D. (1988). The rhythm of everyday life: How Soviet and American citizens use time. Boulder, CO: Westview Press.

Robinson, T.T., & Carron, A.V. (1982). Personal and situational factors associated with dropping out versus maintaining participation in competitive sport. Journal of Sport Psychology,4, 364 - 378.

Sack, H.G. (1980). Zur Psychologie des jungendlichen Leistungssportlers. Eine exemplarishe Längsscnitt-Untersuchung an männlichen und weiblichen Langstreckenläufern über einen Zeitraum von vier Jahren am Ende der Adoleszenz. Schorndorf: Hofman.

Salmons, S., & Henriksson, J. (1981). The adaptive response of skeleton muscle to increased use. Muscle and Nerve,4, 94 - 105.

Salthouse, T.A. (1991). Expertise as the circumvention of human processing limitations. In K.A. Ericsson, & J. Smith (Eds.), Toward a general theory of expertise: Prospects and limits (pp. 286-300). Cambridge, England: C.U.P.

Sapp, M., & Haubenstricker, J. (1978, April). Motivation for joining and reasons for not continuing in youth sports programs in Michigan. Paper presented at AAHPERD annual meeting, Kansas City, MO.

Scheinfeld, A. (1956). The new heredity and you. London: Catte & Windus.

Schulz, R. & Curnow, C. (1988). Peak performance and age among super-athletes: Track and field, swimming, baseball, tennis and golf. Journal of Gerontology, Psychological Sciences,43, 113 - 120.

Silva, J.M., Schultz, B.B., Haslam, R.W., Martin, T.P., & Murray, D.F. (1985). Discriminating characteristics of contestants at the United States Olympic wrestling trials. International Journal of Sport Psychology,16, 79 - 102.

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

Singer, R.N. (1966). Comparison of inter-limb skill achievement in performing a motor skill. Research Quarterly,37, 406 - 410.

Sklad, M. (1973). Rozwoj fizyczny i motorcznosc blizniat. Materialy i Prace Antropologiczne,85, 3 - 102.

Sloboda, J.A., Davidson, J.W., Howe, M.J.A. (1994). Is everyone musical? The Psychologist,7(7), 349 - 354.

Sloboda, J.A., Hermelin, B., & O'Connor (1985). An exceptional musical memory. Musical Perception,3, 155 - 170.

Sloboda, J.A., & Howe, M.J.A. (1991). Biographical precursors of musical excellence: an interview study. Psychology of Music,19, 3-21.

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 Books.

Starkes, J.L. (1987). Skill in field hockey: The nature of the cognitive advantage. Journal of Sport Psychology,9, 146-160.

Starkes, J., Allard, F., Lindley, S., & O'Reilly, K. (1994). Abilities and skill in basketball. International Journal of Sport Psychology,25, 249 - 265.

Starkes, J.L., & Deakin, J. (1984). Perception in sport: A cognitive approach to skilled performance. In W.F. Straub & J.M. Williams (Eds.), Cognitive sport psychology (pp.115-128). Lansing, NY: Sport Science Associates.

Starkes, J.L., Deakin, J., Lindley, S., & Crisp, F. (1987). Motor versus verbal recall of ballet sequences by young expert dancers. Journal of Sport Psychology,9, 222 - 230.

Stones, M.J., & Kozma, A (1981). Adult age trends in athletic performances. Experimental Aging Research,17, 269 - 280.

Stones, M.J., & Kozma, A (1982). Cross-sectional, longitudinal, and secular age-trends in athletic performances. Experimental Aging Research,8, 185 - 188.

Tesch, P.A., & Karlsson, J. (1985). Muscle fibre types and size in trained and untrained muscles of elite athletes. Journal of Applied Physiology, 59, 1716 -1720.

Trussel, E. (1965). Prediction of success in a motor skill on the basis of early learning achievement. Research Quarterly,39, 342 - 347.

Vandenberg, S.G. (1962). The heredity abilities study: Hereditary components in a psychological test battery. American Journal of Human Genetics,14, 220 - 237.

Vispoel, W.P., & Austin, J.R. (1993). Constructive response to failure in music: The role of attribution feedback and classroom goal structure. British Journal of Educational Psychology,63, 110 - 129.

Wallingford, R. (1975). Long distance running. In A.W. Tayler & F. Landry (Eds.), The scientific aspects of sports training (pp. 118-130). Springfield, Il: Thomas.

Weiss, M.R. (1986). A theoretical overview of competence motivation. In M.R. Weiss and D.Gould (Eds.), Sport for children and youths (pp.75-80). Champaign, Ill.: Human Kinetics.

Weiss, V. (1977). Die Heritabilitaten sportlicher tests, berechnet aus den leistungen zehnjahriger zwillingspaare. Arztliche Jugenkunde,68, 197 - 172.

Wilding, J. & Valentine, E. (1994). Memory champions. British Journal of Psychology,85, 231 - 244.

William, L.R.T., & Gross, J.B. (1980). Heritability of motor skill. Acta Genticae Medicae et Gemellologiae,29, 127 - 136.

Williams, H., Woollacott, M., & Ivry, R. (1989). Perceptual-motor timing problems in clumsy children. Paper presented at the 19th annual meeting of the Society for Neuroscience, Phoenix, Arizona.

Table 1
Evaluations For the Wrestling Related and Everyday Activities collapsed across groups (0 = low, 10 = high)

ACTIVITY	Relevance	Effort	Enjoyment	Concentration
Practice others				
mat work	9.82^{H}	9.59^{H}	8.20^{H}	9.45^{H}
jogging	5.94	5.60	4.77	4.25
weights	7.58	8.11	5.80	6.75
running	7.23	7.55^{H}	5.30	5.99
flex.	5.81	5.06	4.83	4.28
swimming	3.15^{L}	5.89	4.15	4.13
cycling	2.74^{L}	4.33	4.59	3.03^{L}
Practice alone				
weights	7.89^{H}	8.54^{H}	5.39	6.59
flexibility	6.73	5.33	3.72^{L}	4.96
running	7.88^{H}	8.34^{H}	5.00	5.31
jogging	6.84	5.90	4.75	3.93^{L}
coach alone	9.15^{H}	6.44	7.61^{H}	8.21^{H}
watching self	7.14	4.03	7.38^{H}	7.83^{H}
swimming	4.08	4.72	5.32	3.52^{L}
cycling	3.87^{L}	5.94	3.37^{L}	3.73^{L}
Wres. Related				
diet	7.32	6.32	1.58^{L}	6.12
reading	4.54	4.60	4.34	6.01
journal	6.74	5.74	4.29	6.37
mental imagery	8.20^{H}	6.01	5.81	7.82^{H}
watching wres.	7.14	4.41	7.46^{H}	6.41
pro. conv.	6.43	4.58	6.63	5.94
Everyday				
sleep	7.77^{H}	1.65^{L}	8.45^{H}	1.11^{L}
study	4.56	8.30^{H}	4.48	8.84^{H}
active leisure	5.34	4.51	8.46^{H}	5.16
work	1.76^{L}	6.45	3.95	6.06
n-active leis.	2.80^{L}	1.26^{L}	7.47^{H}	2.59^{L}

H = significantly higher than the overall mean
L = significantly lower than the overall mean

Table 2
Taxonomy of Wrestling Related and Everyday Activities

The Activity	**number of hours / week**
household chores	
child care	
shopping	
work, not wrestling related	
health and body care	
sleep	
education/study	
active leisure	
travelling	
non-active leisure	
injury rehabilitation	
strength practice alone	
strength practice with others	
fitness training alone	
fitness training with others	
flexibility training alone	
flexibility training with others	
work related to wrestling	
professional conversation	
diet planning/weight loss	
watching wrestling	
wrestling practice alone,or coach	
reading wrestling theory	
keeping a training journal	
wrestling practice with others	
competing	
watching your matches(video)	
mental rehearsal	

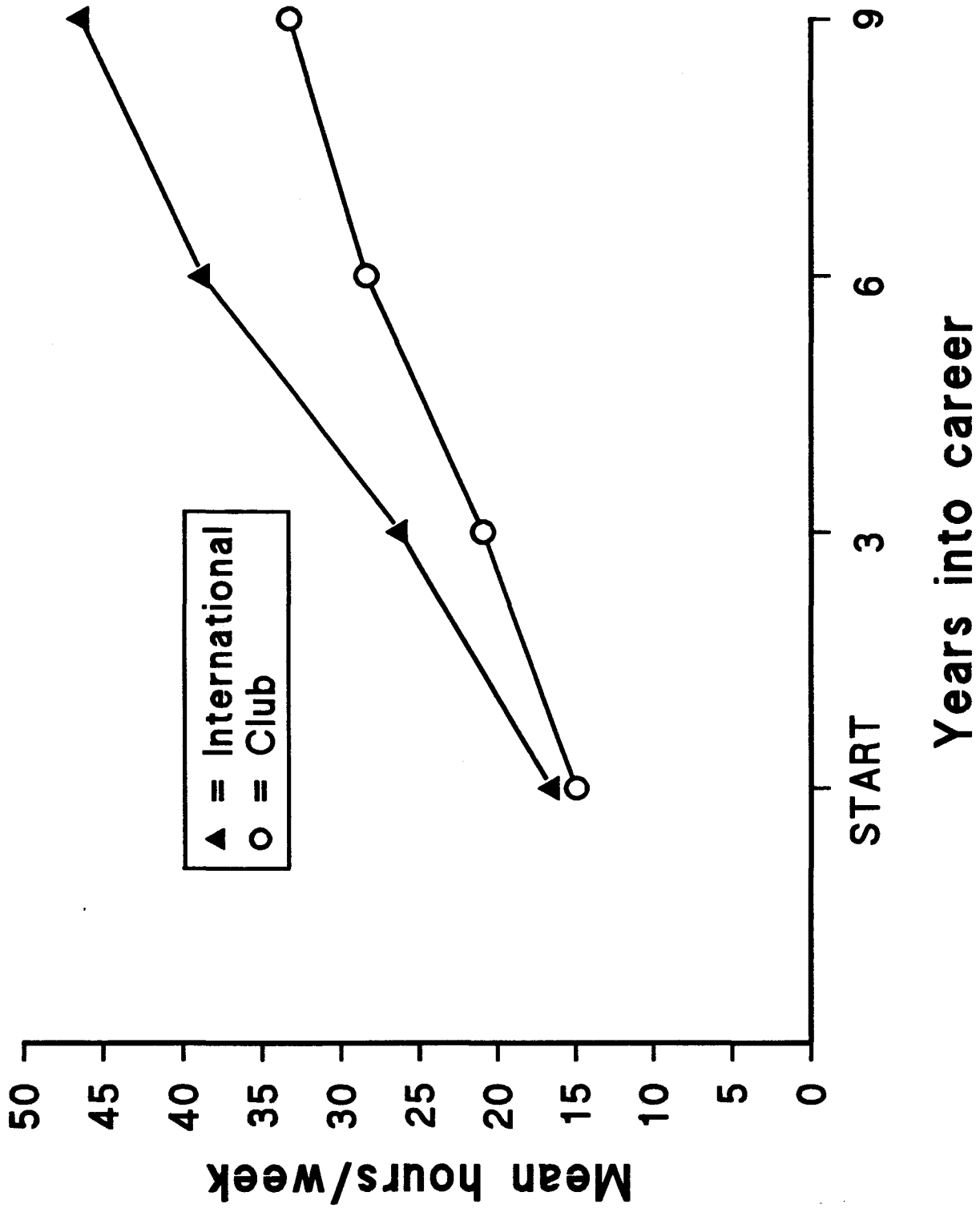
Figure Captions

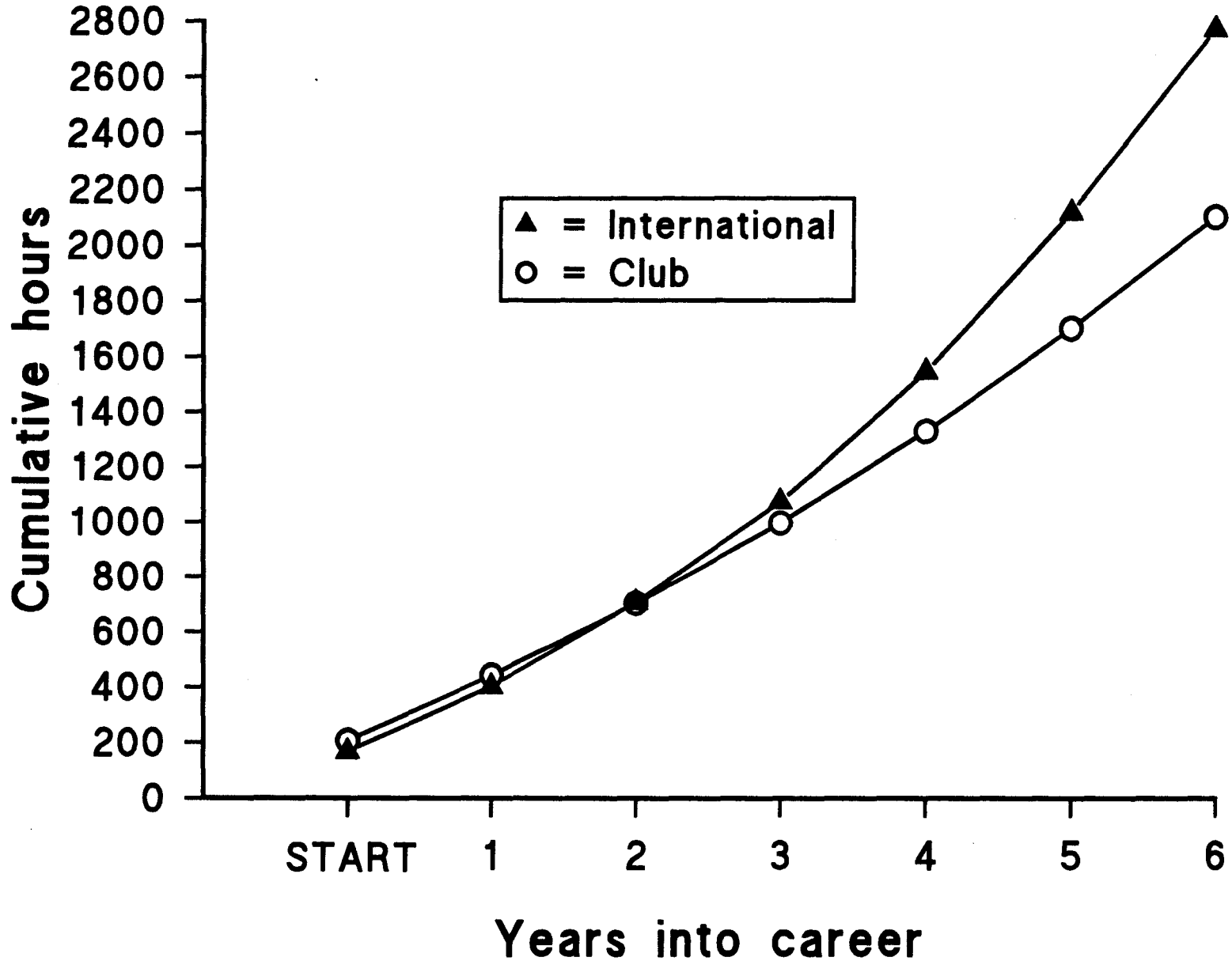
Figure 1. Time spent in all practice activities per week as a function of the number of years wrestling.

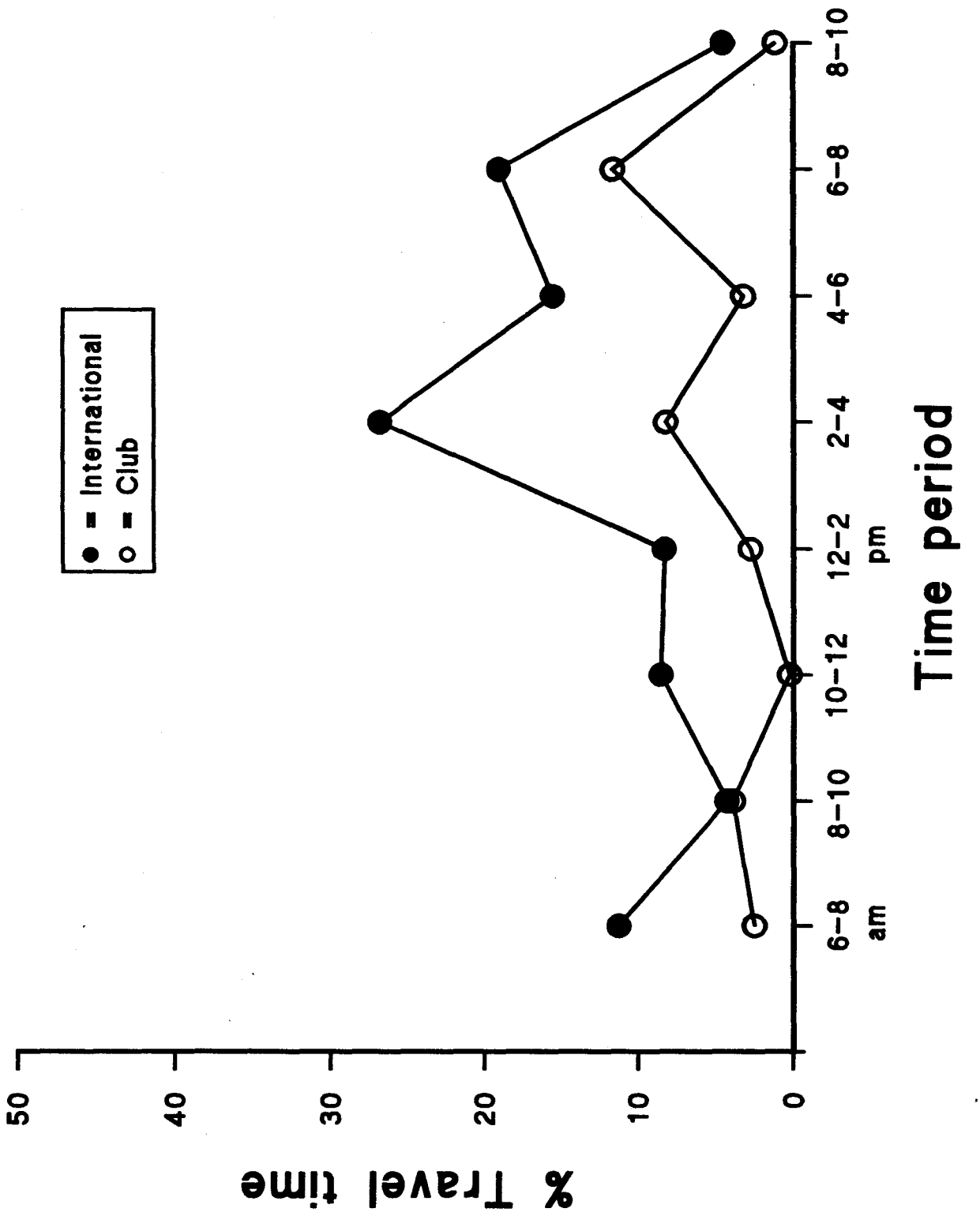
Figure 2. Accumulated practice time with others as a function of the number of years wrestling.

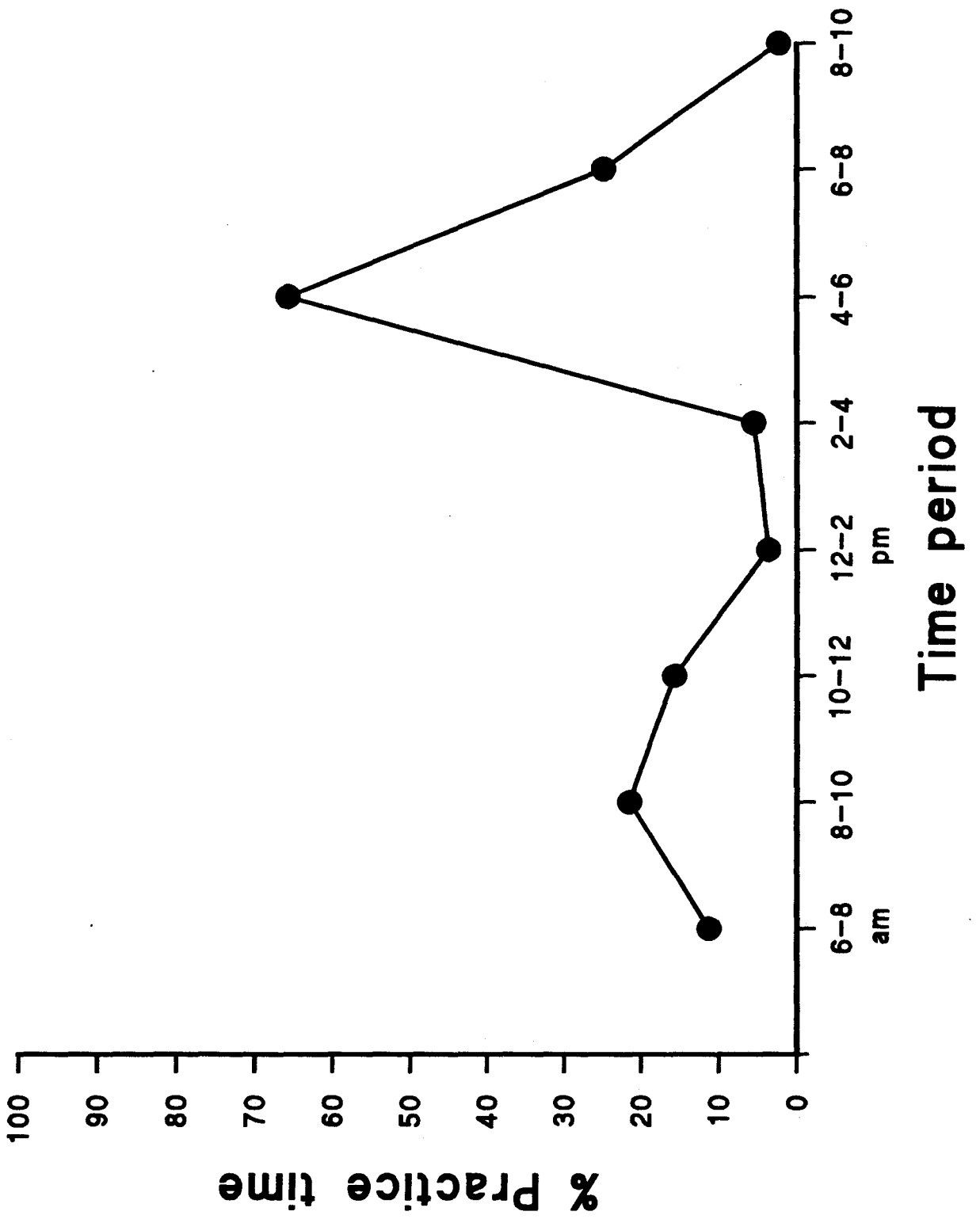
Figure 3. Percentage of time spent travelling as a function of time of day for weekdays only.

Figure 4. Percentage of practice time in all practice activities as a function of time of day for weekdays only.


Mean hours/week
50
45
40
35
30
25
20
15
10
5
0
START
3
6
9
Years into career
▲ = International
o = Club


Cumulative hours
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
▲ = International
o = Club
START
1
2
3
4
5
6
Years into career


● = International
○ = Club
% Travel time
0
10
20
30
40
50
6–8 am
8–10
10–12
12–2 pm
2–4
4–6
6–8
8–10
Time period


% Practice time
100
90
80
70
60
50
40
30
20
10
0
6–8 am
8–10
10–12
12–2 pm
2–4
4–6
6–8
8–10
Time period

APPENDICES

Appendix A (Study 1: Questionnaire)

Name:

Age:

BIOGRAPHIC INFORMATION:

- How old were you when you first began wrestling? _____
- At what age did you begin systematic practice with a coach?_____
- How old were you when you became involved more full-time or on a year round basis, if at all? _____
- What is the highest competitive level you have reached in wrestling so far?

_____
_____
_____
_____

- Please detail your participation and success in competitions along with your respective age.
  (please write on the back of this page if you find you require more space).

Year	Age	Competition (name)	Placing

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

- How many coaches have you had over the course of your career so far?

_____

- What is your nationality? _____

- In what country have you trained primarily to be a wrestler?

_____

- Have you trained in other countries (Y/N)? _____
  IF YES,
  (a) please list the country/countries that you have trained in for more than three months or on a regular basis

_____
_____
_____
_____
_____

  (b) please list the country/countries that you have trained in for less then three months?

_____
_____
_____
_____
_____

ACTIVITY QUESTIONNAIRE

We are interested in finding out what a 'typical week' was like for you at different times through your wrestling career. As you read through the activities, please record by the side of each one how many hours per week, on average, would you have spent engaging in each activity. When you think of a 'typical week' try to think of one occuring mid-way through a competitive season.

The first column will correspond to the age that you first began wrestling. Please write underneath the column headings the ages you were at the specific times. You will probably find that you will not need all of the columns unless you have been wrestling for 18 years or more, therefore please stop when you reach the column corresponding to the age you are now (or the nearest to it). After you have filled in the estimates of time spent in each activity for the first column repeat this procedure for column two, that is for the age you were three years after first beginning wrestling. Continue with this procedure until you reach the column corresponding to the age you are now.

On completion of one section you will be required to rate the activities on various dimensions before going on to the next section. The sections are as follows;

1) practice alone
2) practice with others
3) activities related to wrestling
4) non-wrestling activities

Instructions for completing the ratings will be given at that time.

1) This section refers to practicing alone:

How many hours/week (in a typical week) would you have spent practicing for wrestling alone? This practice would include the following activities;

- weight training
- flexibility training
- running
- jogging
- cycling
- working with the coach
- swimming
- watching your matches on the video

(please write down any other activities you think should be included under this heading, if you feel necessary)

AGE =	start age ____	3 yrs later ____	6 yrs later ____	9 yrs later ____	12yrs later ____	15yrs later ____	18yrs later ____
ACTIVITY							
practice alone							

Please now rate the activities, detailed in the practice alone section, on the following four dimensions;

1) Relevance of the activity to improving performance.
2) How much effort is required to perform the activity.
3) How enjoyable the actual activity itself is (as opposed to the result of the activity).
4) How much concentration is required to perform the activity.

You are required to fill in the table by rating each of the activities using a scale from 0 - 10.

	Relevance to improving wrestling performance 0 - 10 0 = not at all relevant 10 = extremely relevant	Effort required to perform the activity 0 - 10 0 = no effort is required 10 = extreme effort is required	How enjoyable the activity is 0 - 10 0 = not at all enjoyable 10 = extremely enjoyable	How much concentration is required to perform the activity 0 - 10 0 = no concentration is required 10 = extreme concentration is required
ACTIVITY (all performed alone, or with the coach)				
weight training				
flexibilty training				
running				
jogging				
cycling				
working with the coach				
swimming				
watching yourself wrestle on video				

2) This section refers to your practice with others

How many hours would you have spent in a typical week practicing with others? This practice would include the following activities;

- mat work with a partner (sparring)
- weight training
- running
- jogging
- flexibilty training
- swimming
- cycling

	start age	3 yrs later	6 yrs later	9 yrs later	12yrs later	15yrs later	18yrs later
ACTIVITY							
practice with others							

Please now rate each of the activities, detailed in the practice with others section, on the same four dimensions described earlier.

	Relevance to improving wrestling performance 0 - 10 0 = not at all relevant 10 = extrememly relevant	Effort required to perform the activity 0 - 10 0 = no effort is required 10 = extreme effort is required	How enjoyable the activity is 0 - 10 0 = not at all enjoyable 10 = extremely enjoyable	How much concentration is required to perform the activity 0 - 10 0 = no concentration is required 10 = extreme concentration is required
ACTIVITY (performed with partner(s))				
mat work/ sparring				
weight training				
running				
jogging				
flexibility training				
swimming				
cycling				

3) This section refers to activities related to wrestling

How many hours/week (in a typical week) would you have spent in wrestling related activities, these would include the following;

- diet planning
- reading wrestling theory (this could include reading about recommended diets, technique improvement, training methods or psychological training.)
- keeping a training journal
- mental rehearsal (this could be time spent thinking about what happened at practice or in a match.)
- watching wrestling live, on video or TV
- professional conversation (this could be with other wrestlers, referees, coaches, managers, trainers or sport psychologists.)

(please write down any other activities you think should be included under this heading, if you feel necessary)

	start age	3 yrs later	6 yrs later	9 yrs later	12yrs later	15yrs later	18yrs later
ACTIVITY							
time spent in related activities							

Please now rate each of the activities detailed in the wrestling related activities section on the same four dimensions described earlier.

	Relevance to improving wrestling performance 0 - 10 0 = not at all relevant 10 = extremely relevant	Effort required to perform the activity 0 - 10 0 = no effort is required 10 = extreme effort is required	How enjoyable the activity is 0 - 10 0 = not at all enjoyable 10 = extremely enjoyable	How much concentration is required to perform the activity 0 - 10 0 = no concentration is required 10 = extreme concentration is required
ACTIVITY				
diet planning				
reading wrestling theory				
keeping a training journal				
mental rehearsal				
watching wrestling (live/ video/TV)				
professional conversation				

4) This section refers to non-wrestling activities

How many hours in a typical week would you have spent engaging in the following non-wrestling activities;

	start age	3 yrs later	6 yrs later	9 yrs later	12yrs later	15yrs later	18yrs later
ACTIVITY							
sleeping							
academic study/ school.							
active leisure, includes playing other sports							
part / full time work							
* non-active leisure							

* non - active leisure includes things like, watching TV, reading (unrelated to wrestling), playing games(e.g.cards,darts), drinking, socialising, playing a musical instrument, listening to music, theatre going.

Please now rate the activities detailed in the non-wrestling activities section on the same four dimensions described earlier.

	Relevance to improving wrestling performance 0 - 10 0 = not at all relevant 10 = extremely relevant	Effort required to perform the activity 0 - 10 0 = no effort is required 10 = extreme effort is required	How enjoyable the activity is 0 - 10 0 = not at all enjoyable 10 = extremely enjoyable	How much concentration is required to perform the activity 0 - 10 0 = no concentration is required 10 = extreme concentration is required
ACTIVITY				
sleeping				
academic study/ school.				
active leisure				
part/full time work				
non - active leisure				

For the time correponding to the start of your career and the time corresponding to the age you are now or rather your most recent competitive year, please answer the following questions;

- On a yearly basis how many matches would you have wrestled?

	Start of your career	Most recent competitive year
# of matches wrestled		

- On a yearly basis how many competitions would you have entered?

	Start of your career	Most recent competitive year
# of competitions entered		

- On a yearly basis how many clinics would you have attended?

	Start of your career	Most recent competitive year
# of clinics attended		

- On a yearly basis how many clinics would you have given?

	Start of your career	Most recent competitive year
# of clinics given		

- What was the duration of your off-season at different times throughout your career, again use only those columns that you need?

	start age	3 yrs later	6 yrs later	9 yrs later	12yrs later	15 yrs later	18yrs later
duration (wks/mths)							

At the start of your wrestling career you may remember setting yourself various goals to aim for, that may have been very general or quite specific in nature. Can you think back to when your wrestling career first began and list the types of goals you had, including how long or short they would have been.
For example, you may only have wanted to make it into the squad for an upcoming competition in two weeks or you may have wanted to be a national team member. Please be as descriptive as you see necessary.

(continue overleaf if you require more space)

- Now think about the sort of goals you set yourself now and repeat the procedure above for your current goals.

thank you for your partcipation.

Appendix B

Study 1: Competitive success - This year, last year, 2yrs ago & Best Result)

International - current

S. 1)
last year: **no place, Commonwealth champs.**
2nd, Nationals

S. 2)
Best Result: International comps. in national team
this year: 2nd, Senior Nationals
last year: 4th, Senior nationals
2 yrs ago: 1st, CIAU,
4th, Senior Nationals

S. 3)
Best result: International comps.
many Grand prix tourns.

S. 4)
last year: **6th, World age group**
2 yrs ago: 1st, Can. champs.

S. 5)
Best result: International competitor
this year: medalist, National seniors
National team member

S. 6)
this year: 2nd, Can. Sn.
last year: **4th, World Cup**
2 yrs ago: 2nd, Canada Cup

S. 7)
Best result: 4th, Espoir World Cup
last year: **1st, Commonwealth champs.**

S. 8)
Best result: no place, World Champs
this year: 2nd, Can. Sn. Nationals
last year: 3rd, Can. Sn. Nationals.

S. 9)
Best result: 2nd, Pan Ams (age 20)
last year: **3rd, Senior World Cup**

S. 10)
Best result: 7th, espoir World champs.(age 18)
last year: **2-0 World Champs. (Sn.)**
4th, World Cup (Sn)
1st, Can. National champs. (Sn)
2nd, USA International
2 yrs ago: 3rd, World Cup (Sn)
1st, Polish Grand Prix
1st, Can. Nat. champs.

S. 11)
Best result: **8th, World espoir(age 18)**
this year: **5th, World Cup**
1st, Can. Seniors
last year: **1st, Commonwealth champs.**
1st, Slovak Grand Prix
2 yrs ago: 2nd, Can, Seniors

S. 12)
this year: **4th, World Cup**
last year: 1st, USA & Polish Grand Prix
2 yrs ago: 1st, USA NAIA National champs.

S. 13)
this year: 3rd, World Cup
1st, USA Grand Prix
last year: **5th Worlds**
1st/2nd, Polish and Cuban Grand Prix
2nd, Can. champs.
2yrs ago: 3rd, Pan ams.
1st, Olympic trials

S. 14)
Best result: **3rd, Pan Ams(age 25)**
last year: 3rd, Polish Grand Prix
1st, national champs.
4th, World Cup
2 yrs ago: 1st, Czech Grand Prix
9th, Olympic Games

S. 15)
Best result: **3rd, National espoir (age 19)**
3rd, CIAU (age 20)
this year: 1st,Inland Empire Open
1st, Alto Open
last year: 1st, Alto Open
2 yrs ago: 1st at 4, University Opens.

<u>International-retired</u>

S. A)
Best result: **4th, Olympics (age 26)**
1st, Commonwealth, (age 21)
7th, Senoir Worlds, (age 24)
1st, Pan Ams (age 25)

S. B)
Best result: no place, Olympics (age 20, 28)
9th, Olympics (age 24)
1st, Commonwealth (age 19)
1st, National champ (9 times)

S. C
Best result: **1st, Olympics , (age 23)**
1st, World champs. (age 20,21)
3rd, Worlds, (age 26)
Olympic team alternate (age 19)

S. D)
Best result: **no place, Olympic team (age 23)**
8th,World champs, (age 22)
2nd, Pan Am (age 22)

S. E)
Best result: **2nd, Olympic team alternate (age 26)**
Olympic team, 2nd alternate (age 22)
6th, World espoir (age 20)
1st, 2nd, National Sn. Champs.(age 24-25)

S. F)
Best result: **8th, Olympics (age 26)**
last year: no place, World Sn Champs.
2 yrs age: 2nd, Pan Am & Olympic qualifier

S. G)
Best result: 1st, Maccabi games(21, 25, 29yrs)
1st, Olympic team trials(age 20, 28)
2nd, Pan Ams, (age 25)

S. H)
Best result: **7th, World champs. (age 25)**
1st, Commonwealth Games (age 25)

S. K)
Best result: 7th, World champs. (age 23)
no placing, Montreal Olympics (age 22)
2nd, Commonwealth Games(age 24)
1st, Canadian national champs. (age 23,24,25)

S. L)
Best result: **3rd, World champs. (age 27)**
2nd, Commonwealth games(age 31)

Club-current

S. a)
Best result: **8 & 10 yrs ago, 3rd, CIAU**
2 yrs ago: 1st, Ontario senior champs.

S. b)
Best result: **5,6,7 yrs ago = 2nd, CIAUs**
last year: **5th, senior nationals** (same result 5 times!)

S. c)
Best result: **4 yrs ago, 4th, Ontario Junior Champs.**
2 yr ago: no place, Can. espoir champs.
no place, Ontario espoir champs.
3rd, Concordia invitational

S. d)
Best result: **6,7 & 8 yrs ago - 1st at Canadians**

S. e)
Best result: **5 yrs ago, 5th, USA grand nationals**
2 yr ago: 2nd, Ontario espoir provincials

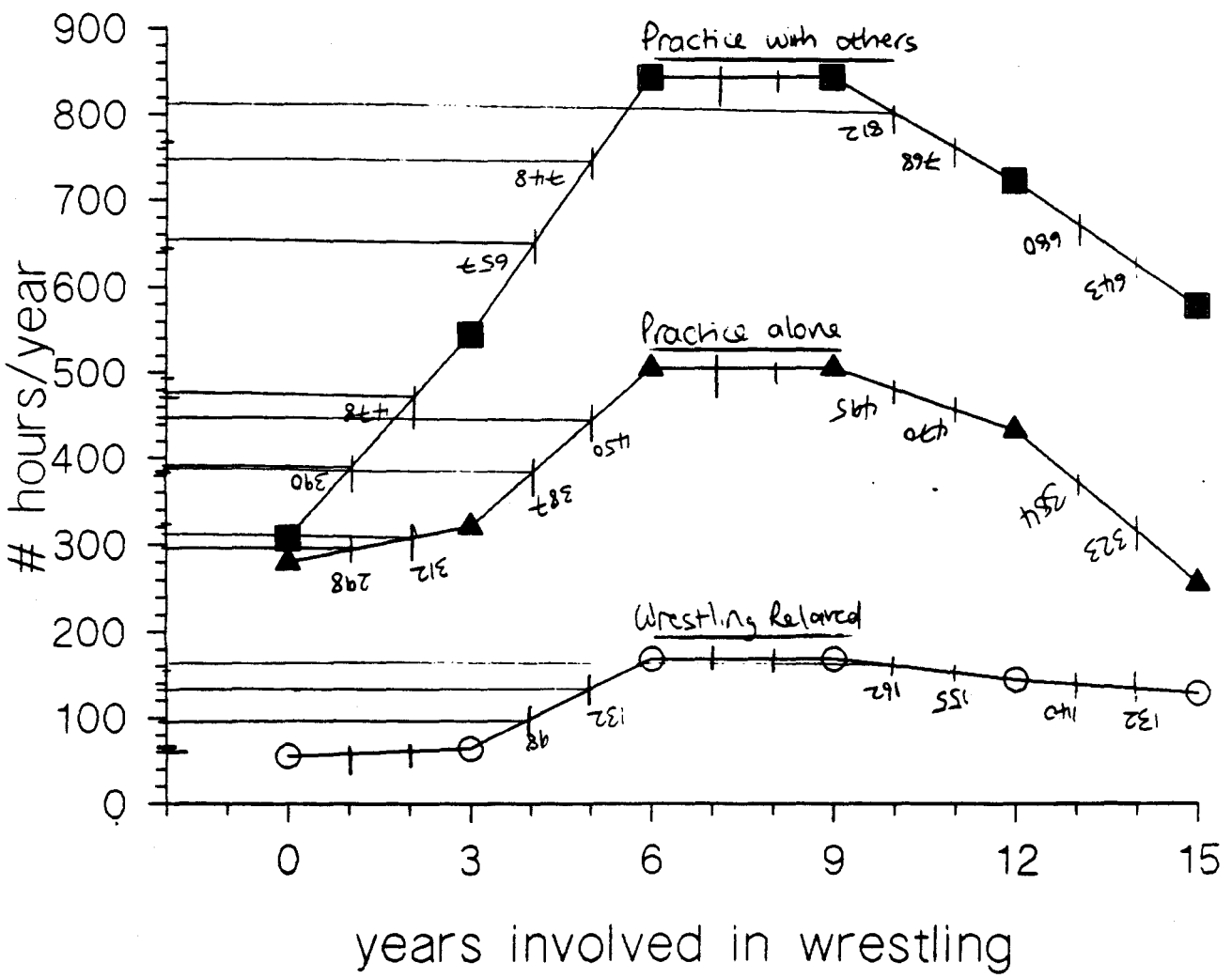
S. f)
Best result: **6,8 & 10 yrs ago - 1st at Nationals**

S. g)
Best result: **1st, Espoir nationals (age 20)**
5th, Canada games (age 18)
this year: 3rd, Manchester Challenge Cup
1st, CIAU
last year: 2nd, CIAU
S. h)
this year: **1st, CIAU**
1st, OUAA
last year: 2nd, CIAU
3rd, OUAA
3rd, Ontario seniors
2yrs ago: 2nd, CIAU
1st, OUAA
2nd, Ontario seniors
S. k)
this year: 2nd, senior provincials
2yrs ago: **1st, senior provincials**

Club-retired
S. i)
Best result: **2nd, Commonwealth champs., Cyprus (age 22yrs)**
3rd, senior nationals(age 21)
national 'B' team
S. ii)
Best result: **1st, CIAU (age 23)**
attend training camps (National team-for 12yrs)
6th, NCAA - All American (age 22)
S. iii)
Best result: **4th, Canadian seniors**
1st, in 13/15 Atlantic comps.
2 yrs ago: 2nd, World Masters champs.
S. iv)
Best result: **1st, CIAU(age 22)**
S. v)
Best result: **3rd, OUAA(age 27 & 29)**
S. vi)
Best result: **4th, CIAU(age 24)**
S. vii)
Best result: **3rd, CIAU(age 22)**
1st, Canada winter games(age 19)
8th, Korean games (age 18)
S. viii)
Best result: **3rd, CIAU(age 22)**

Appendix C

Study 1: Example of line graph used to calculate cumulative practice hours in the intervening years



Appendix D

Table 1

Study 1: Type of goals set by the wrestlers at the start of their career and for the present time: Current wrestlers

Group	Time period: Start	Time period: Current
I-C		
S.1.	to be in top 10 in province	-be on the olympic team -top 10 in the world
S.2.	goals quite limited -make the Ontario High school comp. then place top 6. a national team member	-make olympics (4 yrs) -ST = have 'respectable become placings at int. meets'
S.3.-	make the City team, so compete in Provincials -make Provincial team then national, Olympic/World team	-went to 1992 Olympic trials, now no real goals -just enjoyment, probably - in last competitive year
S.4.-	ST = to win a match -(2 yr goal) to win a tournament -(3yr goal) to win the provincials	-to win Sr. Nationals(2yr goal.) -place well in Int. tourn -make 1994 Olympic team (in 2 yrs)
S.5.-	To be provincial champ at the nationals team	-make national/Olympic - place
S.6.-	win provincials - progress to Nat./Worlds/Olympics	-improve over the year -work on mental/physical state -make the 1996 Olympics
S.7.-	'to improve' -place at High school provincials yrs)	-make '96 Olympic team (2 -get more Int. experience -'do well'at every tourt. -keep life in perspective
S.8-	make High school team -then provincial, national,Olympics -graduate from university, -get a job	-make the Olympic team

S.9.-make the team, to travel
-start to strive for Nat. team success

-**LT** = get Int. medals
-place top 8, '96 Olympics
-**ST** = trials 1995 for Olympics & Pan Ams
-1st Nationals, 1995
-1st Nationals, 1996
-Top 3, Pan Ams

S.10.-win OFSAA,
-then become Espoir & Nat. member

-perform well at worlds
-go to olympics
-"*goals are now more towards the process of winning rather than winning itself.*"

S.11.-win city c/ship
-then make Nat. Espoir team

-win 94 commonwealth
-be medalist at95 Pan Ams
-make the 96 Olympic team
-Every year I aim to win Nationals

S.12.-make it to Nat. level
-began setting, long, short &daily goals etc.

-Tough goals,world medal

S.13.-to win matches
-then, particular tournaments
-then to go to the Olympics
-goals mainly re:high school,provs. and age class Nat. c/ships.

-win the commonwealth games
-place top 6 in Worlds
-**L.T.**=win Olympic/World medal.
-want to be the best wrestler I can possibly be.

S.14.-very general
-do well at tourns. at end of mth.

-more specific expect a particular placing at comps., depending on opponents.
-however, aim to wrestle "*as best I can*"

S.15.-provincial champ.
- then national
-wanted to compete in Int.tourns.
make Alberta team to Canada games.

-continue competing for Canada.
-to actually do well at comps(not just go!).
-be carded

<u>C-C</u>

S.a)-win local high school c/ship
-qualify to OFSAA c/ships
-3 months long

-be medalist at Nat.comp

S.b)-win city c/ships -qualify for OFSAA -be placed at the Nat. cadet c/ships	-To wrestle at Olympics
S.c)S.T-win regionals(1yr goal) **-L.T.** - win OFSAA	-only ST goals -wrestle at a competitive level, so can achieve placing at tourns. -represent Mac. at OUAAs and 'possibly' CIAUs
S.d)- win OFSAA	-be a Nat. team member
S.e)-win High school tourns. win the OUAAs and CIAUs	-'be competitive' in open - tourns. - win Provs./ Nationals
S.f)- Be OFSAA champ	- make the national team
S.g)- To have 'fun'	- Be national team member - improve leg defence -strengthen shoulders /upper body
S.h)- after winning bantam, wanted to win provincial -goals ST, but progressive, i.e. better results/comps.	- still small,ST goals - running 4X/ week -sleeping 7.5hrs/night
S.k)- win OFSAA, high school - go to nationals	- win senior nationals - go to Worlds - go to Olympics - Do as well as possible/comp. - Become carded

Table 1b

Study 1: Type of goals set by the wrestlers at the start of their career and at the peak: Retired wrestlers

	Time Period	
Group	Start	Peak
I-R		
S.B - Prov. High school tourn(1 yr) - always looked for something attainable 'a few notches higher'		-Same difference except jump from Commonwealth to Pan Ams. -goals more specific, i.e cardio., strength,fitness (never give up attitude, drive, inner power) -ultimate =Olympic gold.

S.C- be better than the next guy
- when Espoir World champ,
wanted to be World champ

- knew I hadn't reached peak after first World then champ.,
so goal to continue as long as possible as best
"*even when I left wrestling '84, wanted to come back and be the best.*"

S.D.-Age 14:make high school squad
-Age 17:Prov. & Nat. age champ
-Age 20:Go to Olympics & Nat.champ.

-Age 23-27: Nat. team member/Int. medals.
-Place in top 8 at Worlds
-remain undefeated in prime weight class(Can)

S.E.
-1st yr; win next match any tourn. I didn't win, goal= win it next yr.
-win Ont. High school champ(1 yr)
-goals go more L.T. as progressed.
-make it to '76 Olympics(in 1971)

-more concrete/ specific; - train 10x/week
-to score with a specific move in practice.
-Still dream of going to Olympics.

S.F.
-Age14:be City, then Prov. champ.
-Age 15: aim - Nat. age gp. champ.
-Age 18: aim- Nat. sr. champ/ world age gp. medal.

-21-23yrs:Be in Olympic team
-23-27yrs:aim for World/Olympic medal.

S.G.- no goals beyond next match
- because I enjoyed it,
I constantly explored new techniques

-win nationals
-win medal at Olympics

S.H.-not miss practice,High school
-learn new techniques at practice & try them in scrimmage or comps.
go to University - Engineering
- try to score points off the best older wrestlers. being scored on me.
-go on as many trips, out of town.
-become Provincial wrestling champ.

-make '88 Olympic team(4yrs)
-to medal at '88 Olympics - (2yr goal)
-win Nats.without a point and (yearly)
-to be carded(annual)
-win Nats.-to go to Ints.
-acquire new techniques seen at Int. comps.
-become best athlete I could-fitness/weights
-learn mental training & be able to apply it.

C-R

S.i)- Win Provincials
-get picture up on wall at school
- since 12 yrs wanted to wrestle at Olympics (age 27, gave up)

-be Nat. champ and represent Canada
-ultimate goal =1992 Olympics.

S.ii)-Don't remember setting goals	-'69 - wanted to be Nat. champ -win NCAA tourn.as it was considered too hard for small school athlete.
S.iii)-win a match or 2 in 1st yr. - break even in the 2nd -	-just improve from yr-yr. -improve technique
wrestling a focus, I would have set goals	*"if I'd wanted to make in a different way."*
S.iv)-**S.T**: City champ, place in Regionals, Ontario top 10. -**L.T**: National team junior/senior champ -participate in Olympics	-win medal at Sr. Nats. -beat a Nat. champ -score points on any - wrestler in weight class -visualise a full match with me winning -be in better shape than every one in Canada
S.v)- win City champs.	- perform at best & beat everyone (who's not a Nat.team member) -*"knew that I was unwilling to*
make the sacrifices to be a national team	*member"*
S.vi)- make school team - win a medal - win gold place at all tournaments - try to win every one.	-win AUAAs (ind. & team) -win a medal at CIAUs -not to give up any easy - points go through a tourn. & not get scored upon. -Be technically superior to my opponents.
S.vii)-**S.T**- make grade 7 team - develop some basic techniques - have fun, be part of extra-curric. **L.T.**(2 mths) be Ont. Pee wee champ. - be Elementary City champ	-**S.T**:bring fitness to competitive level - bench press (320lbs) - perfect my fav. techs. **L.T**:- be OUAA champ -be Canada Winter games champ - be CIAU champ
S.viii)-Yr.1:make High school team, place at LOSSA to go to COSSA educator - Yr.2: go to OFSAA - Yr.5: win medal at OFSAA Yr.6: win OUAA medal (Uni. team). - Yr.9: CIAU medal	-developing as a coach/ and - learn about sport and improvements that could - be made

Appendix E :

Study 2: Instructions for diary sheet completion and diary examole (not to scale)

1. RECALLING OF ACTIVITIES ENGAGED IN DURING THE PREVIOUS WEEK

Firstly, think back to your most recent 'typical' week and how you spent your time during this week. Try and remember all the extended activities you undertook, these could be anything from studying, to cleaning the car, to running with a friend or sleeping. These are just a few examples of activities you may have engaged in during last week. Now using the Activity Taxonomy attached, please give an estimate by the side of each activity how many hours you think you spent in each activity, do this first.

2. RECALLING OF ACTIVITIES ENGAGED IN FOR THE UPCOMING WEEK

For the upcoming week (7 DAYS), you are required to keep a 24 hour diary, listing all the activities you engaged in during the day on the accompanying diary sheet, you can be as detailed as you see necessary and use the back of the sheets if you need the space. Be specific as to whether the activity was performed alone or with others, where you see this to be important. For example, whether you watched TV alone or with others is not important to the activity, but whether you went jogging alone or with someone else is. All the answers will be kept strictly confidential, however, if there is an activity engaged in that you consider too personal to disclose on the diary sheet, then please indicate this by marking 'private' in the appropriate box. Please fill out the diary sheet at the end of every day before going to bed and please try and be consistent with this procedure. You can start keeping the diary on any day you wish as long as you keep a diary for a seven day period.

When completing the Diary Sheet, list the activity, and then indicate how long you performed this activity for in the following way;

EXAMPLE

Time	Activity
- 8am	Running alone
8.15am	"
8.30am	"
8.45am	"
- 9am	"
9.15am	Breakfast

In the above example, the person began running alone at 8am, for one hour, then they had their breakfast at 9.15am.

Place each diary sheet in the envelope at the end of each day. Send all the completed diary sheets at the end of the week in the stamped addressed envelope provided. Remember to include the activity taxonomy, biographic information and name each sheet.

THE DIARY (not to scale)

Time	Activity	Time	Activity	Time	Activity	Time	Activity
- 5am		-11am		- 5pm		-11pm	
5.15		11.15		5.15		11.15	
5.30		11.30		5.30		11.30	
5.45		11.45		5.45		11.45	
- 6am		-12pm		- 6pm		-12am	
6.15		12.15		6.15		12.15	
6.30		12.30		6.30		12.30	
6.45		12.45		6.45		12.45	
- 7am		- 1pm		- 7pm		- 1am	
7.15		1.15		7.15		1.15	
7.30		1.30		7.30		1.30	
7.45		1.45		7.45		1.45	
- 8am		- 2pm		-8pm		- 2am	
8.15		2.15		8.15		2.15	
8.30		2.30		8.30		2.30	
8.45		2.45		8.45		2.45	
- 9am		- 3pm		-9pm		- 3am	
9.15		3.15		9.15		3.15	
9.30		3.30		9.30		3.30	
9.45		3.45		9.45		3.45	
-10am		- 4pm		-10pm		- 4am	
10.15		4.15		10.15		4.15	
10.30		4.30		10.30		4.30	
10.45		4.45		10.45		4.45	

Appendix F
Study 2: Answers to long questions

What got you started in wrestling?

International
S1 Friends
S2 Brother (cheaper than hockey)
S3 Brother
S4 Friends
S5 High school coach
S6 Math teacher was a coach
S7 Father was a coach
S8 Always been aggressive. When I did not make the basketball team, chose wrestling.
S9 Friend
S10 Brother

Club
SA coach asked me
SB geog. teach(highschool)
SC grade 10
SD grade 10 gym
SE math teacher
SF High school teacher(grade 9)
SG mother
SH coach -grade 5
SJ friends
SK just tried out in grade 7 & liked it.
SL tried out for High school team in grade 9

How good were you when you first began?

International
S1 Athletic, not a great wrestler
S2 In FIRST year was 2nd in Canada at 16yrs old, next year I was National champ OFSAA.
S3 Won my first tourn. I don't think I was good, but I was small- so most of the athletes were inexperienced.
S4 Had early success for the level I competed at.
S5 Pretty good. Won provincial champs in 1st year.
S6 First tourn - lost both my matches!
S7 Above average - always tough
S8 Won several events
S9 Average, but successful because I was small.
S10 Grade 9, won Can. cadet C/ships.

Club
SA Rookie of the year(quick and flexible)
SB just aggressive and tenacious, lost more than I won.
SC 'crap', I was 195lbs at 15 & kept getting beat up by the older guys.
SD I seemed to excel in gym class
SE average
SF Average

SG successful even from the start
SH Better than average, won Ontario Pee Wee in 1st yr.
SJ fairly good - 2nd Can. Cadet C/ships
SK Average
SL Not bad, but I lacked physical strength

When, if ever, did you first appear to have a natural talent for this event?

International

S1 Grade 11/12(I'm not sure if it was natural talent, ask my coach who is a better judge of this.
S2 3rd year of wrestling
S3 It didn't just appear. One day I decided I wanted to be a good wrestler - & then committed myself.
S4 When I first began - grade 8
S5 After I wrestled my 1st tourn.
S6 Never - It was hard work
"I never thought I had talent for wrestling - I was always good at sports already - I like to think I got to where I am with hard work - that is what separates thoses that are at the top, compared to those who have equal or more talent but are not as successful."
S7 12yrs - began to excel against older adults
S8 Grade 8 - thought I could/or have talent.
S9 Grade 11- started winning at every tournament
S10 Near end of my 1st yr.(grade 9)

Club

SA coach noticed me in grade 9(14) Phys. ed. class
SB Never
SC Never
SD Right from the start
SE Never
SF Second year of wrestling. Beat an OFSAA champ, who'd been wrestling for 4 years.
SG Won the Nationals-1985(13yrs)
SH I think I am talented, did not train much, grades 5-8, but kept winning. Started losing in the later years when people began working harder than me.
SJ By 2nd tourn, in first year.
SK First year
SL Never

APPENDIX G

Statistical Analyses

Table 1a
Study 1: Group mean ages and SDs across the wrestlers' careers

		Age				
Group	n	Now	Began	Systematic	Full-time	Peak
I-C	15					
M		24.07	12.87	13.87	16.80	
SD		1.98	1.86	1.89	1.72	
I-R	10					
M		38.20	13.10	13.40	14.90	25.75
SD		5.10	2.81	3.01	3.53	1.21
C-C	9					
M		24.78	12.67	14.06	15.44	
SD		3.22	2.21	1.17	1.34	
C-R	8					
M		35.88	14.25	15.00	17.71	24.44
SD		8.48	1.98	3.00	2.05	6.31

Table 1b
Study 1: Analysis of variance for age now

Source	MS	df	F	
Skill	6.467	1	.249	
Cohort	1580.000	1	60.851	**
S*C	22.860	1	.881	
Error	25.973	38		

**p< .01

Table 1c
Study 1: Analysis of variance for age when began

Source	MS	df	F
Skill	2.241	1	.413
Cohort	8.194	1	1.510
S*C	4.525	1	.834
Error	5.425	38	

Table 1d
Study 1: Analysis of variance for systematic practice

Source	MS	df	F
Skill	7.945	1	1.322
Cohort	.567	1	.094
S*C	4.944	1	.823
Error	6.009	38	

Table 1e
Study 1: Analysis of variance for full-time

Source	MS	df	F
Skill	5.059	1	.871
Cohort	.325	1	.056
S*C	41.337	1	7.115 *
Error	5.809	38	

*p< .05.

Table 1f
Study 1: Analysis of variance for peak (retired wrestlers)

Source	MS	df	F
Skill	7.656	1	.367
Error	20.834	16	

Table 2a
Study 1: Group means (and SDs) for the number of coaches

Group	n	# of coaches
I-C	15	4.47(1.15)
I-R	10	4.00(2.00)
C-C	9	3.89(1.20)
C-R	8	5.88(2.42)

Table 2b
Study 1: Group means (and SDs) for the number of clinics attended

	Time period	
Group	Start	Present/Peak
I-C	1.47(1.45)	1.87(1.99)
I-R	2.20(3.89)	1.80(2.03)
C-C	2.83(2.21)	0.83(1.62)
C-R	1.19(1.25)	2.31(1.79)

Table 2c
Study 1: Group means (and SDs) for the number of clinics given

Group	Present/Peak
I-C	7.07(8.93)
I-R	3.00(2.04)
C-C	1.72(2.56)
C-R	4.13(4.64)

Table 2d
Study 1: Group means (and SDs) for the number of competitions entered

	Time period	
Group	Start	Present/Peak
I-C	8.70(6.74)	11.83 (6.65)
I-R	7.25(6.30)	16.55 (12.78)
C-C	9.06(6.57)	7.39 (4.96)
C-R	8.50(5.18)	9.81 (4.88)

Table 2e
Study 1: Group means (and SDs) for the number of matches wrestled

	Time period	
Group	Start	Present/Peak
I-C	28.77 (19.75)	45.37 (27.72)
I-R	128.05(274.39)	357.75 (663.92)
C-C	33.00 (19.26)	29.11 (19.13)
C-R	28.38 (15.94)	39.38 (22.79)

Table 2f
Study 1: Analysis of variance, collapsed across "cohort", for number of coaches

Source	MS	df	F
Skill	2.989	1	.870
Error	3.438	40	

Table 2g
Study 1: Analysis of variance, collapsed across "cohort", for the number of clinics attended, for start and the present/peak

Source	MS	df	F
Skill	.001	1	.000
Error	4.17	40	
Career period	1.022	1	.196
S*C	1.879	1	.360
Error	5.220	40	

Table 2h
Study 1: Analysis of variance, collapsed across "cohort", for the number of clinics given, for start and the present/peak

Source	MS	df	F	
Skill	33.863	1	1.829	
Error	18.519	40		
Career period	347.958	1	18.789	**
S*C	33.863	1	1.829	
Error	18.519	40		

**p <.01

Table 2i
Study 1: Analysis of variance, collapsed across "cohort", for the number of competitions entered, for start and the present/peak

Source	MS	df	F
Skill	103.207	1	1.814
Error	56.892	40	
Career period	144.021	1	3.073
S*C	174.021	1	3.713
Error	46.869	40	

Table 2j
Study 1: Analysis of variance, collapsed across "cohort", for the number of matches wrestled, for start and the present/peak

Source	MS	df	F
Skill	153244.292	1	1.406
Error	109028.707	40	
Career period	55736.259	1	2.331
S*C	49310.640	1	2.063
Error	23907.358	40	

Table 3a
Study 1: Group means for the number of hour/week spent in practice time alone, as a function of career

	Number of years							
Group	Start	(n)	3year	6year	9year	(n)	12year	(n)
I-C	6.77	(15)	10.93	16.23	16.50	(11)	19.40	(5)
I-R	3.80	(10)	6.10	10.80	13.15	(10)	12.65	(10)
C-C	6.89	(9)	9.78	11.89	12.14	(7)	18.67	(3)
C-R	3.94	(8)	6.00	9.94	10.71	(7)	9.83	(6)

Table 3b
Study 1: Group means for the number of hour/week spent in practice time with others, as a function of career

	Number of years							
Group	Start	(n)	3year	6year	9year	(n)	12year	(n)
I-C	7.83	(15)	11.00	15.90	19.23	(11)	18.30	(5)
I-R	7.00	(10)	11.10	16.45	18.90	(10)	16.50	(10)
C-C	8.11	(9)	9.89	11.78	11.86	(7)	13.33	(3)
C-R	7.13	(8)	8.50	11.31	11.50	(7)	7.00	(6)

Table 3c
Study 1: Group means for the number of hour/week spent in wrestling related activities, as a function of career

	Number of years							
Group	Start	(n)	3year	6year	9year	(n)	12year	(n)
I-C	4.03	(15)	7.08	10.77	16.66	(11)	11.85	(5)
I-R	2.50	(10)	4.78	5.15	7.45	(10)	6.85	(10)
C-C	1.56	(9)	2.22	4.28	4.86	(7)	6.00	(3)
C-R	2.00	(8)	5.23	7.56	15.36	(7)	16.50	(6)

Table 3d
Study 1: Group means for the number of hour/week spent in all wrestling activities, as a function of career

	Number of years			
Group	Start (n)	3year	6year	9year(n)
Int	16.50(15)	26.20	38.70	46.25(11)
Club	14.91(10)	20.89	28.35	33.21(10)

Table 3e
Study 1: Analysis of variance for the number of hours practicing alone as a function of career (start, 3 and 6year)

Source	MS	df	F
Skill	31.841	1	.25
Cohort	397.422	1	3.123
S*C	17.154	1	.135
Error	127.256	38	
Years	472.696	2	45.134 **
S*Y	19.777	2	1.888
T*Y	4.514	2	.431
S*T*Y	7.857	2	.750
Error	10.473	76	

** p< .01

Table 3f
Study 1: Analysis of variance for the number of hours practicing alone, collapsed across "cohort", as a function of career(start, 3 and 6year)

Source	MS	df	F
Skill	58.636	1	.443
Error	132.308	40	
Years	496.096	2	48.229 **
S*Y	24.064	2	2.339
Error	10.286	80	

** p< .01

Table 3g
Study 1: Analysis of variance for the number of hours practicing with others as a function of the career(start, 3 and 6year)

Source	MS	df	F	
Skill	130.722	1	3.763	
Cohort	7.566	1	.218	
S*C	5.842	1	.168	
Error	34.736	38		
Years	403.774	2	33.041	**
S*Y	58.376	2	4.777	*
T*Y	2.398	2	.196	
S*T*Y	1.139	2	.093	
Error	12.220	76		

* p< .05, ** p< .01

Table 3h
Study 1: Analysis of variance for the number of hours practicing with others, collapsed across time, as a function of career(start, 3 and 6year)

Source	MS	df	F	
Skill	130.447	1	3.919	*
Error	33.286	40		
Years	401.652	2	34.309	**
S*Y	56.620	2	4.837	*
Error	11.707	80		

* p< .05, ** p<.01

Table 3i
Study 1: Analysis of variance for the number of hours in wrestling related activities as a function of career (start, 3 and 6year)

Source	MS	df	F	
Skill	107.842	1	.571	
Cohort	5.928	1	.031	
S*C	218.273	1	1.155	
Error	189.015	38		
Years	193.910	2	13.147	**
S*Y	1.325	2	.090	
T*Y	5.946	2	.403	
S*T*Y	29.759	2	2.018	
Error	14.749	76		

** p< .01

Table 3j
Study 1: Analysis of variance for the number of hours in wrestling related activities, collapsed across "cohort", as a function of career(start, 3 and 6year)

Source	MS	df	F
Skill	158.406	1	.853
Error	185.661	40	
Years	212.217	2	14.166 **
S*Y	3.099	2	.207
Error	14.980	80	

** p< .01

Table 3k
Study 1: Analysis of variance for the number of hours in all wrestling activities as a function of career(start, 3 and 6year)

Source	MS	df	F
Skill	754.098	1	1.368
Cohort	631.057	1	1.145
S*C	272.208	1	.494
Error	551.163	38	
Years	3099.713	2	54.094 **
S*Y	164.457	2	2.870
T*Y	.407	2	.007
S*T*Y	58.671	2	1.024
Error	57.302	76	

** p< .01

Table 3l
Study 1: Analysis of variance for the number of hours in all wrestling activities, collapsed across "cohort", as a function of career(start, 3 and 6year)

Source	MS	df	F
Skill	1002.657	1	1.821
Error	550.561	40	
Years	3228.962	2	57.658 **
S*Y	195.553	2	3.492 *
Error	56.002	80	

* p<.05, ** p<.01

Table 4
Study 1: Group means and SDs for time spent in off-season(month)

		Years into career				
Group		start	3	6	9	12
I-C	M	7.13	4.60	2.75	1.45	1.60
	SD	1.76	2.26	1.95	.57	.89
I-R	M	6.22	3.22	1.35	1.30	1.45
	SD	2.75	1.49	1.01	.79	1.24
C-C	M	4.33	3.00	2.83	3.50	2.67
	SD	1.80	1.32	1.41	1.98	1.53
C-R	M	7.00	6.16	3.59	3.00	3.30
	SD	2.62	1.96	2.13	2.45	3.11

Table 5a
Study 1: Group means and SDs for accumulated practice hours with others as a function of career

		Number of years				
Group		Start	1year	2year	3year	4year
I-C	M	165.07	386.86	670.33	1009.27	1445.33
	SD	87.32	171.74	279.33	422.31	561.43
I-R	M	169.80	424.60	758.90	1163.30	1689.80
	SD	95.39	213.46	374.67	553.56	805.01
C-C	M	251.56	542.11	872.89	1236.44	1623.44
	SD	99.60	192.20	288.92	402.39	493.21
C-R	M	154.50	328.25	509.00	722.00	995.50
	SD	121.98	240.33	368.34	485.84	612.05

		Number of years	
Group		5year	6year
I-C	M	1972.40	2584.13
	SD	717.46	918.10
I-R	M	2325.30	3041.30
	SD	1062.03	1383.44
C-C	M	2035.00	2462.56
	SD	555.79	598.57
C-R	M	1320.88	1690.72
	SD	755.59	934.64

Table 5b
Study 1: Group means and SDs for accumulated practice hours alone as a function of career

		Number of years				
Group		Start	1year	2year	3year	4year
I-C	M	146.93	372.33	664.20	1020.73	1480.40
	SD	154.75	334.58	556.38	815.37	1093.59
I-R	M	83.20	206.50	366.80	564.00	859.00
	SD	116.98	258.69	433.47	641.82	939.53
C-C	M	206.67	466.78	779.67	1139.22	1529.78
	SD	177.40	383.98	619.48	880.19	1126.54
C-R	M	72.75	157.00	252.25	360.00	531.13
	SD	77.77	156.07	238.81	327.73	442.49

		Number of years	
Group		5year	6year
I-C	M	2083.13	2676.87
	SD	1402.34	1742.18
I-R	M	1239.50	1656.10
	SD	1311.61	1753.57
C-C	M	1952.78	2400.78
	SD	1366.44	1605.37
C-R	M	763.75	1047.31
	SD	618.27	870.01

Table 5c
Study 1: Group means and SDs for accumulated hours spent in wrestling related activities as a function of career

		Number of years				
Group		Start	1year	2year	3year	4year
I-C	M	88.27	219.47	390.13	599.53	874.27
	SD	150.53	348.99	594.79	886.62	1250.77
I-R	M	42.80	129.70	259.60	428.60	604.40
	SD	52.53	179.31	383.22	648.14	930.68
C-C	M	44.44	100.89	168.78	247.00	356.78
	SD	41.97	98.03	170.88	261.40	382.36
C-R	M	32.50	96.63	191.25	317.93	495.30
	SD	50.61	146.80	294.47	488.22	777.06

Group		Number of years: 5year	6year
I-C	M	1209.07	1596.13
	SD	1685.86	2180.41
I-R	M	804.10	1026.40
	SD	1215.72	1512.88
C-C	M	497.00	665.89
	SD	533.82	720.67
C-R	M	717.68	973.66
	SD	1150.43	1577.61

Table 5d
Study 1: MANOVA statistics for accumlated practice hours with others as a function of career

Source	df	Rao's R
Skill	7,32	2.345 *
Cohort	7,32	1.866
S*C	7,32	1.252

* p< .05

Univariate Fs for the effect of Skill:

	Number of years: Start	1	2	3	4	5	6
F ratio	1.284	.215	.053	.508	1.697	3.513	5.380*

* p< .05

Table 5e
Study 1: MANOVA statistics for accumlated practice hours alone as a function of career

Source	df	Rao's R
Skill	7,32	1.082
Cohort	7,32	1.638
S*C	7,32	.669

Table 5f
Study 1: MANOVA statistics for accumlated hours spent in wrestling related activities as a function of career

Source	df	Rao's R
Skill	7,32	1.127
Cohort	7,32	1.017
S*C	7,32	1.105

Table 5g
Study 1: MANOVA statistics for accumlated hours spent in all wrestling activities as a function of career

Source	df	Rao's R
Skill	7,32	1.523
Cohort	7,32	1.291
S*C	7,32	1.024

Table 6a
Study 1: Accumulated practice hours with others as a function of age

	Age							
Group	n	13	n	14	n	15	n	16
I-C	9	371.89	12	503.42	13	729.54	15	949.40
I-R	3	788.33	7	609.29	8	848.75	10	1022.10
C-C	3	542.00	7	551.86	8	798.13	9	497.14
C-R	4	123.50	4	205.00	6	309.33	7	1041.11
	n	17	n	18	n	19	n	20
I-C	15	1353.47	15	1862.93	15	2474.33	13	3171.54
I-R	10	1456.60	10	1985.80	10	2597.70	10	3297.80
C-C	9	1401.11	9	1793.67	9	2204.78	9	2636.33
C-R	7	778.57	8	994.50	8	1348.38	8	1752.63
	n	21	n	22	n	23		
I-C	11	4075.91	11	4872.45	7	5733.86		
I-R	10	4090.00	9	5094.67	9	5997.89		
C-C	9	3087.89	8	3680.38	5	4366.20		
C-R	8	2194.88	8	2615.72	7	3003.14		

Table 6b
Study 1: Analysis of variance for differences in accumulated practice hours with others as a function of age

Source	MS	df	F
15years			
Skill	132536.301	1	.799
Error	165908.639	17	
14years			
Skill	134216.186	1	.598
Error	224288.114	29	
15years			
Skill	291574.405	1	.854
Error	341318.369	33	
16years			
Skill	299993.912	1	.569
Error	526971.128	39	
17years			
Skill	690146.740	1	.911
Error	757466.719	39	
18years			
Skill	2474330.828	1	2.308
Error	1072049.749	40	
19years			
Skill	5273659.977	1	3.579
Error	1473444.862	40	
20years			
Skill	9891947.713	1	4.916 *
Error	2012298.892	38	
21years			
Skill	18809632.244	1	7.144 **
Error	2633048.134	36	
22years			
Skill	29586254.258	1	8.531 **
Error	3467962.325	34	
23years			
Skill	36617465.003	1	7.469 *
Error	4902804.841	26	

* $p < .05$, ** $p < .01$

Table 6c
Study 1: Accumulated practice hours alone as a function of age

	Age							
Group	n	13	n	14	n	15	n	16
I-C	9	371.33	12	502.17	13	723.38	15	954.47
I-R	3	294.71	7	454.75	8	582.30	10	857.70
C-C	3	475.14	7	711.25	8	961.56	9	1322.78
C-R	4	123.50	4	205.00	6	309.33	7	1041.11
	n	17	n	18	n	19	n	20
I-C	15	1384.33	15	1922.67	15	2564.00	13	3213.15
I-R	10	1208.10	10	1638.40	10	2101.60	10	2627.70
C-C	9	1716.33	9	2135.44	9	2579.22	9	3039.22
C-R	7	778.57	8	994.50	8	1348.38	8	1752.63
	n	21	n	22	n	23		
I-C	11	4172.73	11	4966.64	7	5441.71		
I-R	10	3136.78	9	3706.56	9	4286.67		
C-C	9	3808.75	8	4953.60	5	7170.00		
C-R	8	2194.88	8	2615.72	7	3003.14		

Table 6d
Study 1: Accumulated hours spent in wrestling related activities as a function of age

	Age							
Group	n	13	n	14	n	15	n	16
I-C	9	86.44	12	196.50	13	346.00	15	493.20
I-R	3	64.33	7	95.43	8	172.00	10	243.90
C-C	3	41.33	7	77.29	8	133.13	9	187.67
C-R	4	114.25	4	238.00	6	277.00	7	387.34
	n	17	n	18	n	19	n	20
I-C	15	744.33	15	1062.47	15	1437.87	13	1971.77
I-R	10	404.40	10	608.10	10	846.10	10	1092.20
C-C	9	268.78	9	377.44	9	510.22	9	674.56
C-R	7	584.91	8	723.30	8	1036.05	8	1490.68
	n	21	n	22	n	23		
I-C	11	2876.91	11	3508.39	7	3493.76		
I-R	10	1363.00	9	1509.22	9	1813.22		
C-C	9	854.11	8	1062.88	5	1806.20		
C-R	8	2083.43	8	2686.15	7	3574.34		

Table 7a
Study 1: Group means for the number of hours/week spent in active leisure

	Years into Career				
Group	Start	3year	6year	9year	12year
I-C	14.87	12.27	8.93	8.09	6.40
I-R	12.30	10.90	8.00	6.83	7.06
C-C	8.78	8.33	6.67	6.93	4.00
C-R	10.13	10.13	10.13	9.71	8.67

Table 7b
Study 1: Group means for the number of hour/week spent in non-active leisure

	Years into Career				
Group	Start	3year	6year	9year	12year
I-C	21.47	23.97	24.50	19.36	18.40
I-R	13.00	15.00	14.80	15.80	17.35
C-C	17.50	16.50	17.00	19.67	17.50
C-R	13.38	14.00	15.75	16.86	19.00

Table 7c
Study 1: Group means for the number of hour/week spent sleeping

	Years into Career				
Group	Start	3year	6year	9year	12year
I-C	54.37	52.33	51.93	56.00	56.60
I-R	60.20	57.90	57.20	56.65	56.15
C-C	59.00	52.75	52.13	54.50	49.67
C-R	57.13	52.25	52.13	50.71	48.83

Table 7d
Study 1: Group means for the number of hour/week spent working (non-wrestling related)

	Years into Career				
Group	Start	3year	6year	9year	12year
I-C	6.47	8.50	14.33	12.83	14.83
I-R	2.70	3.90	8.10	11.10	21.10
C-C	2.89	3.89	6.67	17.79	31.67
C-R	5.50	7.25	20.31	6.86	36.67

Table 7e
Analysis of variance for the number of hours spent in everyday activities as a function of career (start, 3year, 6year)

Source	MS	df	F
Active leisure			
Skill	233.356	1	1.270
Error	183.794	40	
Years	71.846	2	4.144 *
S*Y	24.433	2	1.409
Error	17.338	80	
Non-active leisure			
Skill	469.660	1	.891
Error	527.306	39	
Years	29.949	2	.935
S*Y	15.510	2	.484
Error	32.037	78	
Sleep			
Skill	14.513	1	.096
Error	150.491	39	
Years	207.706	2	11.872 **
S*Y	31.559	2	1.804
Error	17.496	78	
Work			
Skill	2.071	1	.012
Error	168.170	40	
Years	715.655	2	6.381 **
S*Y	17.596	2	.157
Error	112.150	80	

* $p < .05$, ** $p < .01$

Table 8a
Study 1: Analysis of variance for differences in the ratings (relevance, effort, enjoyment, concentration) for each practice alone activity

Source	MS	df	F	
Working alone with the coach				
Skill	32.576	1	4.217	*
Error	7.726	34		
Rating	43.978	3	17.251	**
S*R	.163	3	.064	
Error	2.549	102		
Watching yourself on video				
Skill	51.803	1	4.952	*
Error	10.461	32		
Rating	100.882	3	22.183	**
S*R	3.391	3	.746	
Error	4.548	96		
Weight(strength)training alone				
Skill	.732	1	.063	
Error	11.608	37		
Rating	74.220	3	20.394	**
S*R	1.459	3	.401	
Error	3.639	111		
Running alone				
Skill	2.575	1	.402	
Error	6.404	36		
Rating	107.429	3	23.006	**
S*R	3.666	3	.785	
Error	4.670	108		
Swim alone				
Skill	12.368	1	.778	
Error	15.907	27		
Rating	37.962	3	7.557	**
S*R	7.502	3	1.493	
Error	5.023	81		
Jog alone				
Skill	.344	1	.021	
Error	16.616	32		
Rating	55.338	3	11.975	**
S*R	8.358	3	1.809	
Error	4.621	96		

Flexibility training			
Skill	24.833	1	1.851
Error	13.418	37	
Rating	57.901	3	12.221 **
S*R	3.499	3	.738
Error	4.738	111	
Cycling			
Skill	22.273	1	1.582
Error	14.080	26	
Rating	16.312	3	3.648 *
S*R	3.503	3	.783
Error	4.472	78	

* p< .05, ** p< .001

Table 8b
Study 1: Analysis of variance for differences in the ratings (relevance, effort, enjoyment, concentration) for practice with others

Source	MS	df	F
Cycling			
Skill	.330	1	.019
Error	17.015	28	
Rating	23.684	3	8.628 **
S*R	1.239	3	.451
Error	2.745	8	
Flexibility			
Skill	3.256	1	.210
Error	15.537	34	
Rating	13.758	3	3.376
S*R	5.045	3	1.238
Error	4.076	102	
Jogging			
Skill	16.886	1	.907
Error	18.611	31	
Rating	19.057	3	5.511
S*R	4.916	3	1.422
Error	3.458	93	

Mat work			
Skill	2.185	1	1.679
Error	1.301	40	
Rating	21.554	3	17.708 **
S*R	.459	3	.377
Error	1.217	120	
Running			
Skill	2.301	1	.168
Error	13.683	38	
Rating	42.659	3	11.486 **
S*R	3.076	3	.828
Error	3.714	114	
Swimming			
Skill	2.335	1	.168
Error	13.911	28	
Rating	37.338	3	6.771 **
S*R	6.783	3	1.230
Error	5.515	84	
Weight (strength) training			
Skill	23.093	1	1.070
Error	21.582	36	
Rating	35.905	3	14.483 **
S*R	1.273	3	.514
Error	2.479	108	

* p< .05, ** p< .01

Table 8c
Study 1: Analysis of variance for differences in the ratings (relevance, effort, enjoyment, concentration)for wrestling related activities

Source	MS	df	F
Professional Conversation			
Skill	17.645	1	1.619
Error	10.898	35	
Rating	29.635	3	7.823 **
S*R	.923	3	.244
Error	3.788	105	

Diet

Skill	7.694	1	.395
Error	19.488	35	
Rating	233.916	3	49.228 **
S*R	6.006	3	1.264
Error	4.752	105	

Keeping a training journal

Skill	.739	1	.038
Error	19.339	34	
Rating	39.881	3	14.536 **
S*R	2.437	3	.888
Error	2.744	102	

Mental rehearsal

Skill	12.615	1	1.373
Error	9.185	37	
Rating	56.987	3	14.793 **
S*R	4.380	3	1.137
Error	3.852	111	

Reading wrestling material

Skill	85.419	1	5.027 *
Error	16.993	35	
Rating	21.313	3	5.046 **
S*R	.566	3	.134
Error	4.223	105	

Watching wrestling

Skill	21.917	1	1.517
Error	14.449	35	
Rating	65.187	3	17.794 **
S*R	2.917	3	.796
Error	3.663	105	

* $p<.05$, ** $p<.01$

Table 8d
Study 1: Spearman rank correlations between the mean ratings for all the wrestling activities

	n	Ed^2	Rho
Relevance and effort:	21	493.5	.680 **
Relevance and enjoyment:	21	628.5	.592 **
Relevance and concentration:	21	265.5	.828 **
Effort and enjoyment:	21	1384.0	.101
Effort and concentration:	21	984.0	.361
Enjoyment and concentration:	21	562.0	.635 **

* p<.05, ** p<.001

Table 8e
Study 1: Analysis of variance for differences in the ratings (relevance, effort, enjoyment, concentration) for everyday activities

Source	MS	df	F
Active Leisure			
Skill	5.954	1	.398
Error	14.963	40	
Rating	126.032	3	25.219 **
S*R	11.334	3	2.268
Error	4.998	120	
Non-Active leisure			
Skill	.001	1	.000
Error	12.913	40	
Rating	309.059	3	68.451 **
S*R	3.686	3	.816
Error	4.515	120	
Sleeping			
Skill	16.141	1	1.266
Error	12.750	39	
Rating	594.570	3	97.259 **
S*R	9.721	3	1.590
Error	6.113	117	

Studying			
Skill	.562	1	.073
Error	7.662	39	
Rating	219.471	3	32.309 **
S*R	4.301	3	.633
Error	6.793	117	
Working			
Skill	35.127	1	1.864
Error	18.848	35	
Rating	172.092	3	30.114
S*R	4.009	3	.701
Error	5.715	105	

* p< .05, ** p<. 01

Table 9a
Study 2: Group mean ages and SDs across the wrestlers' careers

			Ages		
Group	n	Now	Began	Systematic	Full-time
Int.	10				
M		25.10	13.10	14.00	16.90
SD		2.42	2.38	2.06	3.21
Club	11				
M		23.09	13.50	15.45	17.23
SD		3.39	2.34	1.77	1.40

Table 9b
Study 2: Analysis of variance for ages

Source	MS	df	F
Age: now			
Skill	21.143	1	2.394
Error	8.832	19	
Age: began			
Skill	.658	1	.735
Error	5.559	19	
Age: systematic practice			
Skill	11.082	1	3.042
Error	3.644	19	

Age: full-time

Skill	.561	1	.095
Error	5.925	19	

Table 10a
Study 2: Means and SDs, number of coaches

Group	# coaches	
International	M	4.60
	SD	1.26
Club	M	3.64
	SD	1.57

Table 10b
Study 2: Means and SDs for the number of competitions entered

		Time period	
Group		Start	Present
International	M	9.90	9.00
	SD	6.70	5.40
Club	M	15.45	7.95
	SD	25.03	4.20

Table 10c
Study 2: Means and SDs for the number of matches wrestled

		Time Period	
Group		Start	Present
International	M	40.25	38.05
	SD	32.16	18.70
Club	M	86.09	50.18
	SD	156.71	60.85

Table 10d
Study 2: Analysis of variance for the number of coaches

Source	MS	df	F
Skill	4.864	1	2.373
Error	2.050	19	

Table 10e
Study 2: Analysis of variance for the number of competitions entered at the start and for the current year

Source	MS	df	F
Skill	53.250	1	.300
Error	177.613	19	
Career period	184.800	1	.941
S*C	114.086	1	.581
Error	196.300	19	

Table 10f
Study 2: Analysis of variance for the number of matches wrestled at the start and for the current year

Source	MS	df	F
Skill	8802.192	1	1.121
Error	7851.165	19	
Career period	3803.650	1	.495
S*C	2976.031	1	.388
Error	7678.329	19	

Table 11a
Study 2: Group means (and SDs) for the total time spent in wrestling related activities during the diary week (hrs)

		Group	
Activity		International	Club
Wrestling	M	9.03	9.80
	SD	2.27	4.29
Work(wrestling)	M	5.40	1.59
	SD	8.52	3.16
Weight monitor.	M	1.41	1.69
	SD	1.43	1.14
Watching wres.	M	0.00	1.48
	SD		2.65
Stretch/Flex	M	.68	.34
	SD	.92	.59
Strength-others	M	1.30	.59
	SD	2.12	1.60
Strength-alone	M	1.28	3.56
	SD	1.47	4.25
Professional conv.	M	.38	.73
	SD	.69	1.50
Mental rehearsal	M	.35	.16
	SD	.59	.39

Injury rehab.	M	.55	.33
	SD	1.16	.75
Fitness-others	M	.55	.20
	SD	.73	.27
Fitness-alone	M	2.48	2.67
	SD	1.64	1.79
Competing	M	1.48	2.14
	SD	3.14	3.60

Table 11b
Study 2: Group means (and SDs) for the total time spent in everyday activities in a one week period (hour)

		Group	
Activity		International	Club
Work	M	12.53	8.59
	SD	16.53	11.65
Travel	M	17.40	6.25
	SD	5.36	5.49
T.V./Video	M	12.05	12.73
	SD	9.75	6.76
Studying	M	8.10	19.23
	SD	14.68	14.31
Socialising	M	6.24	7.90
	SD	2.28	8.05
Sleeping	M	55.45	57.11
	SD	6.27	8.92
Rest	M	1.33	.27
	SD	2.08	.40
Non-active leis.	M	17.55	17.66
	SD	9.30	6.82
Housework	M	3.50	1.90
	SD	2.63	1.46
Health/personal	M	6.66	6.67
	SD	2.22	2.98
Eating	M	9.99	8.57
	SD	3.81	2.81
Active leisure	M	3.94	6.55
	SD	3.15	6.58

Table 11c
Study 2: Analysis of variance for the diary totals - wrestling related activities

Source	MS	df	F
Wrestling			
Skill	3.109	1	.257
Error	12.094	19	
Work(wrestling related)			
Skill	76.000	1	1.916
Error	39.674	19	
Weight monitoring			
Skill	.413	1	.218
Error	1.895	19	
Watching wrestling			
Skill	11.431	1	3.089
Error	3.70	19	
Stretch/Flexibility			
Skill	.629	1	1.068
Error	.589	19	
Strength training with others			
Skill	2.634	1	.782
Error	3.369	19	
Strength training alone			
Skill	27.273	1	2.592
Error	10.522	19	
Professional conversation			
Skill	.650	1	.502
Error	1.294	19	
Mental rehearsal			
Skill	.191	1	.796
Error	.240	19	

Injury rehabilitation			
Skill	.255	1	.275
Error	.927	19	
Fitness with others			
Skill	.625	1	2.038
Error	.307	19	
Fitness alone			
Skill	.200	1	.068
Error	2.964	19	
Competing			
Skill	2.291	1	.206
Error	11.097	19	

Table 11d
Study 2: Analysis of variance for the diary totals - everyday activities

Source	MS	df	F
Work			
Skill	81.070	1	.404
Error	200.801	19	
Travel			
Skill	651.213	1	22.113 **
Error	29.449	19	
TV			
Skill	2.403	1	.033
Error	72.239	19	
Study			
Skill	648.561	1	3.250
Error	199.432	19	
Socialising			
Skill	14.438	1	.274
Error	52.772	19	

Sleeping			
Skill	14.497	1	.240
Error	60.494	19	
Rest			
Skill	5.800	1	2.725
Error	2.128	19	
Non-active leisure			
Skill	.062	1	.001
Error	67.303	19	
Housework			
Skill	13.448	1	3.050
Error	4.406	19	
Personal hygiene/health			
Skill	.000	1	.000
Error	7.001	19	
Eating			
Skill	10.552	1	.981
Error	10.756	19	
Active leisure			
Skill	35.627	1	1.29
Error	27.501	19	

* p< .05, ** p< .01

Table 12a
Study 2: Group mean percentages for time spent travelling as a function of time of day (for weekdays only)

	Time of day							
	am			pm				
Group	6-8	8-10	10-12	12-2	2-4	4-6	6-8	8-10
Int.	11.25	4.25	8.50	8.25	26.75	15.50	19.00	4.50
Club	2.50	3.86	.23	2.73	8.18	3.18	11.59	1.14

Table 12b
Study 2; Analysis of variance for the percentage of time spent travelling as a function of time of day (6am - 10pm, 2 hour blocks)

Source	MS	df	F
Skill	2731.657	1	10.937 **
Error	249.759	19	
Time period	620.961	7	6.621 **
S*T	162.288	7	1.730
Error	93.784	133	

** p< .01

Table 13a
Study 2: Group means and SDs for the the number and duration of practice sessions

		Practice session	
Group		# of sessions	duration (hour)
International	M	8.80	1.85
	SD	2.04	.31
Club	M	11.45	1.51
	SD	3.24	.34

Table 13b
Study 2: Analysis of variance for the number of practice sessions

Source	MS	df	F
Skill	36.911	1	4.927 *
Error	7.491	19	

* p< .05

Table 13c
Study 2: Analysis of variance for the duration of practice sessions(hour)

Source	MS	df	F
Skill	.576	1	5.445 *
Error	.106	19	

* p< .05

Table 14a
Study 2: Group means and SDs for time spent(hour) in practice activities as a function of the day of the week

		Day of week						
Group		Mon	Tues	Wed	Thur	Fri	Sat	Sun
Int:	M	3.00	3.11	2.88	2.85	1.93	.80	.58
	SD	1.02	1.13	1.20	1.32	1.05	.93	1.23
Club:	M	3.18	2.93	2.89	3.09	3.16	1.02	.82
	SD	.98	1.20	1.45	1.29	1.52	.90	.68

Table 14b
Study 2: Analysis of variance for the distribution of practice activities as a function of the day of the week (7 days)

Source	MS	df	F
Skill	2.855	1	1.156
Error	2.471	19	
Day	22.669	6	19.689 **
S*D	1.057	6	.918
Error	1.151	114	

** p< .01

Table 14c
Study 2: Group means for time spent (hour) in wrestling practice as a function of the day of the week

		Day of week					
Group		Mon	Tues	Wed	Thur	Fri	Weekend
Int:	M	2.05	1.95	1.50	2.08	.93	.53
Club:	M	2.00	1.89	1.64	1.80	1.75	.73

Table 14d
Study 2: Analysis of variance for the distribution of time spent in wrestling practice as a function of the day of the week (5 days and weekend)

Source	MS	df	F
Skill	.518	1	.257
Error	2.016	19	
Day	5.894	5	12.567 **
S*D	.760	5	1.62
Error	.469	95	

Table 14e
Study 2: Group means for time spent (hour) in fitness activities alone as a function of the day of the week

		Day of week					
Group		Mon	Tues	Wed	Thur	Fri	Weekend
Int:	M	.23	.43	.30	.83	.35	.35
Club:	M	.50	.32	.34	.47	.45	.52

Table 14f
Study 2: Analysis of variance for the distribution of time spent in fitness activities alone as a function of the day of the week (5 days and weekend)

Source	MS	df	F
Skill	.014	1	.028
Error	.499	19	
Day	.280	5	1.267
S*D	.268	5	1.399
Error	.221	95	

Table 14g
Study 2: Group means and sds for time spent (hour) in fitness activities with others as a function of the day of the week

		Day of week					
Group		Mon	Tues	Wed	Thur	Fri	Weekend
Int:	M	.15	.05	.08	.08	.05	.08
Club:	M	.14	.07	.00	.00	.00	.05

Table 14h
Study 2: Analysis of variance for the distribution of time spent in fitness activities with others as a function of the day of the week (5 days and weekend)

Source	MS	df	F
Skill	.044	1	.972
Error	.045	19	
Day	.038	5	1.030
S*D	.007	5	.188
Error	.037	95	

Table 15
Correlations between time spent in leisure activities and wrestling related activities

	n	r
All leisure activities		
All wrestlers	21	.292
International	10	.325
Club	11	.237
Active leisure		
All wrestlers	21	.265
International	10	.074
Club	11	.527 *
Non-active leisure		
All wrestlers	21	.109
International	10	.284
Club	11	-.263

* $p < .05$

Table 16a
Study 2: Correlations between recent week estimates and diary data for wrestling related activities

	r
All practice with others	
Int	.66 *
Club	-.16
All practice alone	
Int	.37
Club	.66 *
Competing	
Int	.58 *
Club	.62 *
Diet	
Int	.47
Club	-.50
Fitness alone	
Int	-.13
Club	.47

Fitness other	
Int	.35
Club	-.68 **
Flex.stretch alone	
Int	.21
Club	-.10
Injury rehab.	
Int	.05
Club	.44
Mental rehearsal	
Int	.06
Club	.65 *
Wrestling others	
Int	.76 **
Club	.15
Pro. Conversation	
Int	.51
Club	.53
Strength alone	
Int	.96 **
Club	-.19
Strength other	
Int	.98 **
Club	-.06
Work (wres)	
Int	.80 **
Club	.96 **

* p< .05, ** p< .01, df = 7

Table 16b
Study 2: Correlations between recent week estimates and diary data for everyday activities

	r
Active leisure	
Int	.46
Club	.17
Health/personal	
Int	.06
Club	-.42

Housework	
Int	.65 *
Club	.25
N-active leisure	
Int	.32
Club	-.10
Shopping	
Int	.75 **
Club	-.57
Sleep	
Int	.48
Club	.74 **
Study	
Int	.98 **
Club	.83 **
Travel	
Int	.77 **
Club	.64 *
Work	
Int	.84 **
Club	.94 **

* p< .05, ** p< .01, df = 7

Table 17a
Study 2: Group means and SDs for estimates of time spent in wrestling related activities in a recent typical week (hour)

		Group	
Activity		International	Club
Diet planning	M	1.95	3.35
	SD	1.57	6.23
Fitness alone	M	3.30	5.10
	SD	2.26	4.38
Fitness others	M	3.85	4.10
	SD	6.39	2.51
Flexibility alone	M	1.70	.60
	SD	1.06	.74
Flexibility other	M	.30	.00
	SD	.67	
Injury rehab.	M	1.75	1.70
	SD	1.81	1.83
Training journal	M	1.15	.55
	SD	1.20	1.26

Mental rehearsal	M	1.73	3.70
	SD	1.53	2.94
Wrestling alone	M	2.90	2.40
	SD	5.49	3.53
Wrestling others	M	12.10	9.45
	SD	3.60	2.67
Professional conv.	M	2.20	2.90
	SD	2.98	3.93
Strength alone	M	3.10	2.55
	SD	2.44	2.50
Strength others	M	1.30	2.90
	SD	1.95	4.95
watch yself(video)	M	.70	.73
	SD	.95	1.01
Watching others	M	1.80	3.05
	SD	3.01	3.98
Wrestling work	M	3.75	5.90
	SD	4.96	10.20
Competing	M	3.90	3.85
	SD	3.94	3.67

Table 17b
Study 2: Analysis of variance for the recent, typical week estimates: Wrestling related activities

Source	MS	df	F
Strength alone			
Skill	1.800	1	.302
Error	5.958	18	
Strength others			
Skill	12.800	1	.904
Error	14.167	18	
Injury Rehabilitation			
Skill	.113	1	.032
Error	3.463	18	
Fitness alone			
Skill	12.800	1	1.060
Error	12.078	18	
Fitness others			
Skill	.313	1	.013
Error	424.925	18	

Flexibility alone			
Skill	4.050	1	4.190
Error	.967	18	
Flexibility others			
Skill	.450	1	.771
Error	10.500	18	
Work, wrestling related			
Skill	23.113	1	.359
Error	64.363	18	
Professional conversation			
Skill	2.450	1	.201
Error	12.167	18	
Diet monitoring			
Skill	9.800	1	.475
Error	20.625	18	
Watching wrestling			
Skill	7.813	1	.627
Error	12.463	18	
Wrestling alone			
Skill	2.450	1	.074
Error	33.294	18	
Training journal			
Skill	1.800	1	1.189
Error	1.514	18	
Wrestling others			
Skill	19.503	1	2.175
Error	8.968	18	
Competing			
Skill	.012	1	.001
Error	14.468	18	

Mental rehearsal			
Skill	19.503	1	3.558
Error	5.481	18	

Table 17c
Study 2: Group means and SDs for estimates of time spent in everyday activities in a recent typical week (hour)

		Group	
Activity		International	Club
Work	M	16.66	5.80
	SD	17.14	8.15
Travel	M	8.53	3.55
	SD	3.64	3.37
Studying	M	10.95	18.75
	SD	18.04	11.02
Sleeping	M	49.95	56.06
	SD	6.31	12.17
Non-active leis.	M	17.20	23.70
	SD	11.71	8.88
Housework	M	3.98	4.50
	SD	2.17	4.09
Health/personal	M	3.85	6.40
	SD	2.08	3.40
Active leisure	M	9.60	6.05
	SD	11.95	5.48
Childcare	M	1.80	.30
	SD	5.03	.67

Table 17d
Study 2: Analysis of variance for the recent, typical week estimates: Everyday activities

Source	MS	df	F
Work			
Skill	588.613	1	3.268
Error	180.118	18	
Sleep			
Skill	186.050	1	1.980
Error	93.969	18	

Study			
Skill	304.200	1	1.361
Error	223.436	18	
Active leisure			
Skill	63.013	1	.730
Error	86.368	18	
Non-active leisure			
Skill	211.250	1	1.956
Error	107.983	18	
Travel			
Skill	123.753	1	10.055 **
Error	12.307	18	
All everyday activities			
Skill	463.973	1	.707
Error	656.618	18	

** p <.01

Table 18a
Study 2: Analysis of variance for differences between the diary and recent week estimates for wrestling related activities

Source	MS	df	F
Diet planning			
Skill	6.602	1	.688
Error	9.589	18	
Rec/Diary	10.506	1	.813
S*R	3.452	1	.267
Error	12.917	18	
Fitness alone			
Skill	11.854	1	1.300
Error	9.116	18	
Rec/Diary	23.601	1	3.962
S*R	5.059	1	.849
Error	5.957	18	

Fitness others			
Skill	.014	1	.001
Error	12.511	18	
Rec/Diary	128.702	1	11.273 **
S*R	.827	1	.072
Error	11.417	18	
Flexibility alone			
Skill	5.347	1	6.602 **
Error	.810	18	
Rec/Diary	4.813	1	7.498 *
S*R	1.360	1	2.118
Error	.640	18	
Flexibility others			
Skill	.225	1	.771
Error	.292	18	
Rec/Diary	2.025	1	6.943 *
S*R	.225	1	.771
Error	.292	18	
Injury rehabilitation			
Skill	.285	1	.114
Error	2.505	18	
Rec/Diary	14.854	1	8.376 **
S*R	.141	1	.080
Error	1.773	18	
Journal			
Skill	.756	1	1.011
Error	.748	18	
Rec/Diary	6.806	1	8.743 **
S*R	1.056	1	1.357
Error	.778	18	
Mental rehearsal			
Skill	8.100	1	2.478
Error	3.268	18	
Rec/Diary	60.025	1	24.358 **
S*R	11.556	1	4.690 *
Error	2.464	18	

Wrestling others

Skill	19.952	1	1.609
Error	12.399	18	
Rec/Diary	33.764	1	6.799 *
S*R	15.314	1	3.084
Error	4.966	18	

Professional conversation

Skill	3.164	1	.359
Error	8.802	18	
Rec/Diary	38.514	1	8.197 *
S*R	.189	1	.040
Error	4.699	18	

Strength others

Skill	2.256	1	.203
Error	11.115	18	
Rec/Diary	12.656	1	1.921
S*R	12.656	1	1.921
Error	6.587	18	

Strength alone

Skill	11.963	1	1.328
Error	9.005	18	
Rec/Diary	.791	1	.105
S*R	27.019	1	3.603
Error	7.499	18	

Watching y/self on video

Skill	.003	1	.006
Error	.482	18	
Rec/Diary	5.134	1	10.661 **
S*R	.003	1	.006
Error	.482	18	

Watching wrestling

Skill	13.225	1	1.636
Error	8.083	18	
Rec/Diary	36.100	1	5.035 *
S*R	.100	1	.014
Error	7.169	18	

Work (wrestling related)			
Skill	7.877	1	.090
Error	87.724	18	
Rec/Diary	16.577	1	.812
S*R	92.264	1	4.521 *
Error	20.410	18	
Competing			
Skill	1.702	1	.082
Error	20.625	18	
Rec/Diary	38.514	1	7.297 *
S*R	2.139	1	.405
Error	5.278	18	

* p< .05, ** p< .01

Table 18b
Study 2: Analysis of variance for differences between the diary totals and recent week estimates for everyday activities

Source	MS	df	F
Non-active leisure			
Skill	75.625	1	.746
Error	101.409	18	
Rec/Diary	100.806	1	1.392
S*R	140.625	1	1.941
Error	72.434	18	
Childcare			
Skill	1.914	1	.260
Error	7.371	18	
Rec/Diary	5.439	1	.827
S*R	11.289	1	1.716
Error	6.579	18	
Health/personal care			
Skill	18.906	1	3.501
Error	5.400	18	
Rec/Diary	24.414	1	2.544
S*R	13.806	1	1.439
Error	9.596	18	

Housework			
Skill	3.525	1	.359
Error	9.807	18	
Rec/Diary	25.400	1	5.114
S*R	12.156	1	2.520
Error	4.967	18	
Active leisure:			
Skill	3.525	1	.050
Error	69.839	18	
Rec/Diary	83.016	1	1.820
S*R	87.394	1	1.916
Error	45.618	18	
Shopping			
Skill	.039	1	.024
Error	1.619	18	
Rec/Diary	12.939	1	8.661 **
S*R	.014	1	.009
Error	1.494	18	
Sleeping			
Skill	179.564	1	1.410
Error	127.384	18	
Rec/Diary	132.314	1	4.838
S*R	34.689	1	1.268
Error	27.349	18	
Studying			
Skill	1086.806	1	2.763
Error	393.382	18	
Rec/Diary	.506	1	.028
S*R	68.906	1	3.834
Error	17.974	18	
Travel			
Skill	709.806	1	21.388 **
Error	33.188	18	
Rec/Diary	294.306	1	42.092 **
S*R	119.025	1	17.023 **
Error	6.992	18	

Work

Skill	642.002	1	1.815
Error	353.674	18	
Rec/Diary	16.577	1	.572
S*R	80.514	1	2.777
Error	28.990	18	

* p< .05, ** p< .01

Table 19a
Study 2: Skill rankings assigned to the international wrestlers by expert coaches

	Rank score			
Subject #	Coach 1	Coach 2	Coach 3	FINAL
1	3	4	3	3
2	4	5	7	5
3	1	1	1	1
4	6	7	6	6
5	9	10	10	10
6	5	3	4	4
7	2	2	2	2
8	8	8	5	8
9	10	9	9	9
10	7	6	8	7

Table 19b
Study 2: Skill rankings assigned to the club wrestlers by their coach

Subject #	Rank score
1	9
2	5
3	10
4	8
5	7
6	6
7	3
8	4
9	1
10	2

Table 19c
Study 2: Regression analysis for the international wrestlers' rank, as accounted for by the diary values for practice with others(hour)

Source	MS	df	F
Regression	.970	1	.095
Residual	10.191	8	

y = .113x + 4.267

Table 19d
Study 2: Regression analysis for the club wrestlers' rank as accounted for by the diary values for practice with others(hour)

Source	MS	df	F
Regression	23.567	1	3.199
Residual	7.367	8	

y = -.444x + 10.236

Table 19e
Study 2: Regression analysis for the international wrestlers' rank as accounted for by the diary values for practice alone(hour)

Source	MS	df	F
Regression	.296	1	.029
Residual	10.275	8	

y = -.074x + 5.778

Table 19f
Study 2: Regression analysis for the club wrestlers' rank as accounted for by the diary values for practice alone(hour)

Source	MS	df	F
Regression	30.838	1	4.775
Residual	6.458	8	

y = .373x + 3.382

Table 19g
Study 2: Regression analysis for the international wrestlers' rank as accounted for by accumulated practice hours with others

Source	MS	df	F
Regression	9.272	1	.89
Residual	10.422	8	

y = -.0004x + 7.823