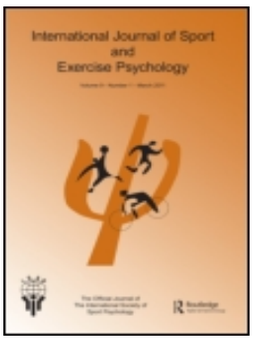

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Characteristics of Expert Development in Rhythmic Gymnastics: A Retrospective Study

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Abstract

The development of expertise for two groups of rhythmic gymnasts was studied where a group of elite (Olympic) gymnasts was compared to a group of sub-elite (International) gymnasts. Structured interviews were used to collect retrospective information about the gymnasts' health, training resources, level and ranking, and hours spent in training activities. The gymnasts rated practice activities during the last period of their development (age 16 and older) with respect to their perceived physical effort, mental concentration, and fun. The Olympic gymnasts were involved in significantly fewer activities and sports throughout their development compared to the International gymnasts. All gymnasts reported engaging in five practice activities of warm-up, ballet, technique training, routines, and conditioning in their rhythmic gymnastics training. Olympic gymnasts allocated substantially more time to the practice activities of ballet, technique, routines, and conditioning, compared to the International gymnasts. Olympic gymnasts also rated their health as lower than the International gymnasts. All gymnasts reported that the practice activities of technique and routine training required more physical effort and mental concentration than warm-up, ballet, and conditioning. The Olympic gymnasts reported experiencing less fun in their participation overall. The findings of this study provide a comprehensive description of early activity involvement, training activities, training resources, and health and injury ratings of expert level rhythmic gymnasts and help to further the understanding of how to assess sport expertise development.

Keywords: expertise, development, training activities

The theoretical framework of deliberate practice (Ericsson, Krampe & Tesch-Römer, 1993) proposed that the acquisition of expert performance in various domains can be explained by extended engagement in deliberate practice activities. Deliberate practice

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activities are designed to improve specific aspects of the current level of performance by offering "repeated experiences, where the individual can attend to the critical aspects of the situation and incrementally improve her/his performance in response to knowledge of results and/or feedback from a teacher" (Ericsson et al., 1993, p. 368). The improvements from deliberate practice are gradual, and many years of deliberate practice are required to attain expert levels of performance (Ericsson, 1998; Ericsson & Lehmann, 1996). In fact, even the most "talented" individuals need around 10 years of practice before they win an international competition (Simon & Chase, 1973).

The quality and quantity of practice activities can also explain individual differences in attained performance in many domains of expertise. In their studies of expert musicians, Ericsson et al. (1993) found that these musicians spent 50-60 hours a week on music-related activities, and the duration of some types of practice activities were found to predict one's level of achievement as an adult. The most effective training activities (i.e., deliberate practice) were those that had been designed specifically by a coach or teacher. During deliberate practice the musicians focused on improving particular aspects of their performance with high levels of effort/concentration, and they emphasized the instrumental value of the activity rather than its inherent enjoyment. Ericsson et al. (1993) found that the amount of time individual musicians had spent on this type of solitary practice during development was positively correlated with their attained level of performance.

The retrospective interview approach developed by Ericsson et al. (1993) was modified by Hodges and Starkes (1996) into questionnaires that could be distributed to performers in the athletic domain. Hodges and Starkes (1996) collected information on the characteristics of international and club level wrestlers' specific training practice activities during their development. The wrestlers also rated each activity with respect to how relevant they perceived it to be for improving performance, how much mental concentration and physical effort was required, and how much enjoyment was derived from engaging in the activity. Supporting the importance of practice as a determinant of elite performance, Hodges and Starkes (1996) found that, at six years into their careers, the international level wrestlers spent reliably more time on all of their training activities related to wrestling than did the club-level wrestlers.

Overall, the questionnaire approach of Hodges and Starkes (1996) had difficulties identifying specific training activities in sport that met the characteristics of deliberate practice, where individual differences in level of engagement by athletes explain levels of attained performance. Although their questionnaires asked athletes to rate the perceived relevance of many current training activities, the researchers were not able to collect information about the accumulated engagement in those activities during development and, thus, could not assess the relation between past engagement and current performance. To address this challenge, Starkes et al. (1996) proposed that researchers should search for training activities that matched some characteristics of deliberate practice in music; namely activities "rated very high on relevance for performance, high on effort, and comparatively low on inherent enjoyment" (Ericsson et al., 1993, p. 373).

This questionnaire procedure was later adapted in several other studies of athletes in different sports (Helsen, Starkes & Hodges, 1998; Hodge & Deakin, 1998; Starkes, Deakin, Allard, Hodges, & Hayes, 1996). In an early study of figure skaters, Starkes et al. (1996) showed that skaters' performances improved as a function of the number of active hours in training and the number of years of skating. Similarly, Hodge and Deakin's (1998) study of martial artists showed a "steady increase in the estimates of time that the martial artists participated *in all of the activities* related to karate as they advanced through their belt classifications" (p. 274). Helsen et al. (1998) extended this methodology to the realm of the team sports of soccer and field hockey. Based on questionnaires from international, national, and provincial players in both sports, Helsen et al. (1998) found that higher level of achievement in the sport was associated with a greater amount of time accumulated in training during development.

Consistent with the search for practice activities meeting the subjective criteria for deliberate practice (Starkes et al., 1996), empirical studies (Helsen et al., 1998; Hodge & Deakin, 1998; Hodges & Starkes, 1996; Starkes et al., 1996) found that most activities judged by athletes to be relevant to improvement of performance in their respective domains were also perceived to require a higher level of either concentration or effort. However, these studies also found that many of the activities judged by the athletes to be relevant to improvement in their performance (thus meeting a subjective criterion of deliberate practice) were also rated high in enjoyment and, by inference, would be spontaneously engaged in for their own sake. These findings were presented as being inconsistent with Ericsson et al.'s (1993) finding that expert musicians did not rate their activity of deliberate solitary practice as more enjoyable than other daily activities. This discrepancy may, at least in part, be explained by different definitions of enjoyment and other procedural differences between the studies on sports and the original study on expert musicians. In the study of musicians, the experts were interviewed individually and instructed to rate the inherent enjoyment of the ongoing activity and explicitly disregard the consequences of activity, such as the personal satisfaction of reaching a higher level of mastery (for a discussion see Ericsson, 1996, 2001, 2003).

There are some more fundamental differences between the original study in music and the subsequent search for practice activities judged to be relevant to improvement in sports. The original concept of deliberate practice (Ericsson et al., 1993) was developed as an extension of the research on learning with feedback and repetition in the laboratory as "a highly structured activity, the explicit goal of which is to improve performance. Specific tasks are invented to overcome weaknesses, and performance is carefully monitored to provide cues for ways to improve it further" (p. 368). Based on a task analysis, solitary practice in music was identified as an activity motivated solely by the music experts' effort to improve their performance of specific pieces and mastering new techniques, thus meeting the conceptual criteria for deliberate practice. Most importantly, Ericsson et al. showed that musicians were able to estimate the amount of time that they engaged in solitary deliberate practice and that the estimated durations were related to individual differences in attained music performance. They also demonstrated how the estimated amount of deliberate practice was related to objectively measured

performance on representative music tasks between experts and amateurs, as well as within a group of expert pianists. These differences in the studies of the acquisition of expert performance in music and in sports raise the issue of whether the differences between the results found in these domains reflect differences in methodology and approaches. If a similar approach to those applied in music were to be applied in a domain of sports, one could examine the extent to which a similar pattern of results would be obtained in the two types of domains of expertise.

The current study was motivated by our attempt to understand practice and other types of activities that mediate the development of very high levels (i.e., International vs. Olympic) of performance in the sport. In order to reconcile the findings obtained from the study of the development of expert performance in sport and music, we selected an individual sport because of the relative ease in defining practice activities matching the conceptual criteria of deliberate practice. Several domains of motor performance are suitable in this regard, including figure skating, ballet, gymnastics, diving, and swimming. We selected rhythmic gymnastics because gymnasts in this sport engage in specific types of practice activities on a consistent daily basis. Therefore, these gymnasts would be able to provide a reliable assessment of their weekly practice duration retrospectively. We relied on a new interview instrument (Côté, Ericsson, & Law, 2005) that was designed to describe the development of athletic performance in a manner consistent with the expert-performance approach used to study expert musicians (Ericsson, 2003; Ericsson et al., 1993; Ericsson & Smith, 1991). The interview was designed to capture the progression of skill acquisition and the change in the structure of the sporting experience at different ages and ability levels, as well as how these relate to the development of expertise (Côté, 1999).

Based on the findings of recent studies using the new interview procedure, Côté, Baker, and Abernethy (2003) proposed a developmental approach to the acquisition of expertise that promotes appropriate developmental activities and sport skills suitable to each stage of growth. Côté and colleagues' studies (Côté, 1999; Baker, Côté, Abernethy, 2003a; Baker, Côté, & Deakin, 2005; Soberlak & Côté, 2003) have found that early sport diversification, high amounts of "deliberate play," and child-centered coaches and parents appear to be common characteristics of environments for children involved in sport under the age of 13. For example, Baker, Côté, and Abernethy (2003b) found that involvement in competition (i.e., deliberate play) was rated during a retrospective interview as the most important form of training by expert athletes in team sports. Further, Abernethy, Baker, and Côté (2005) recently demonstrated that expert team-sport athletes who had been involved in several other sports consistently outperformed non-experts in a recall task of defensive players' position. In sum, these studies show that involvement in deliberate play and engagement in several sports at a young age may have influenced attained expert performance by encouraging later specialization in one sport and future investment in deliberate practice activities.

Ward, Hodges, Williams, and Starkes (2004) recently critiqued the developmental approach suggested by Côté and colleagues. They reported evidence that the duration of deliberate play and the sampling of various sports were not predictive of attained

level of performance in English soccer players, only the duration of domain-specific practice reliably accounted for performance differences between elite and sub-elite soccer players. However, Côté and colleagues' accumulated evidence shows how early involvement in activities that are not solely designed to improve performance (i.e., deliberate play and engagement in other sports) may still influence the attainment of expert performance. This may be a "less costly" path toward sport expertise (Côté, 2004; Côté et al. 2003) rather than the optimal predictors of elite levels of performance. In a recent review Baker and Côté (2006) attempted to reconcile these contradictory findings and proposed that sampling and deliberate play in the early years of sport participation might lead to more enjoyment, less physical injuries, and a lower likelihood of dropping out in youth sport, thus indirectly contributing to the attainment of adult expert-level performance. The current study was designed to enhance our understanding of pre-requisites and earlier developmental phases leading to elite levels of performance.

Our new interview instrument (Côté, Ericsson, & Law, 2005) was designed to capture the overall development of elite athletes and how it depends on the successful acquisition of skills, and the availability of training resources, as well as preserved health. Following the expert performance approach (Ericsson, 2003; Ericsson et al., 1993; Ericsson & Smith, 1991), we attempt to identify training activities in rhythmic gymnastics, where increased engagement is associated with a higher level of attained performance, and then examine how these training activities are rated in terms of effort, concentration, and inherent enjoyment.

There is limited research on how expert performance is acquired in rhythmic gymnastics. In a study by Hume, Hopkins, Robinson, et al. (1993), 106 rhythmic gymnasts were tested on a number of variables to predict their level of attainment by examining physical, psychological, and training attributes that correlated with performance. Hume et al. (1993) used various physical measures such as VO2 max and flexibility, as well as psychological questionnaires and self-reports (of training duration) to gather information about the athletes' participation. Findings indicated that the amount of training throughout the athletes' development showed a strong relationship with level of attainment in rhythmic gymnastics. In addition, the findings showed that there was a dramatic increase in time devoted to the sport between the badge level (M = 10.9 + 2.9 years old) and the elite grades (M =18.5 + 2.1 years old) and that this increase of weekly training time led to improvements in performance. Interestingly, the athletes in the study described as being at the elite level continued to engage in other activities while training in rhythmic gymnastics. The issue that developed when examining athletes in this study is that their sample was deemed to be elite in comparison to other individuals in the country but not by their overall world ranking.

Rhythmic gymnastics is a sport where the athletes move into "high performance and skill perfection stages" as young as 15 years old (Federation Internationale de Gymnastique, 2005a, p. 34). Rhythmic gymnasts at the international level have been reported to engage in a small number of activities before investing in rhythmic gymnastics, and often these activities are closely related to gymnastics: for example, ballet or music training (Beamer, Côté, & Ericsson, 1999). Since this sport is characterized by athletes, reaching

peak performance at young ages, it requires athletes to specialize and invest early in their sporting career, which can impact on the gymnasts' health. Kellman (2002) outlines that higher training amounts and the integration of more technically challenging routines of gymnasts increases their risk of injury. These training amounts and changes in routines are due to the athletes progressing through the different levels of competition. At each level athletes are required to master increasingly difficult movements which are set out by the international sport regulatory bodies. Evidently, these requirements can impact on the athletes' health and thus this is an important issue to address in the development of elite rhythmic gymnasts.

As with many other sports, the selection to national teams is characterized by gymnasts competing at local levels and progressing to national competitions where they are selected for national teams to represent their respective countries. Interestingly, the world rankings in rhythmic gymnastics have been dominated by the former Soviet Union countries and Eastern and Southern European nations since the early 1960s (Federation Internationale de Gymnastique, 2005b).

Therefore, our study focused on the highest levels of rhythmic gymnastics performance and contrast the best rhythmic gymnasts in the world to other less accomplished gymnasts competing at the international level. We compared two groups of elite rhythmic gymnasts who have made full-time commitments to excel in their sport, yet attained different levels of performance in their domain. It was proposed that there may be significant differences between the groups in their early activity involvement, hours spent in training activities, and ratings of training resources and health, that would help to explain these differing levels of performance.

Method

Participants

Purposive sampling (Patton, 2002) was used in order to select two groups of rhythmic gymnasts who would illustrate the differences between an Olympic level of achievement and gymnasts who have competed at the international level but never reached the top world ranking. All of these gymnasts competed in the individual competition (one gymnast performing one routine) until age 12.5 (SD = 1.1) when they were selected to compete on the national team in the group routine (a group of gymnasts performing one routine). The Olympic group consisted of a team of six senior level gymnasts who were ranked second in the world in rhythmic gymnastics group competition at the time of the interview. The International group consisted of a team of six rhythmic gymnasts who were on a senior national team and were ranked first in their country, but had never placed higher than 10th at the World level and were ranked 13th in the world standings at the time of study. The average age of the participants across both groups at the time of the interview was 17.3 years old (SD = 1.6; Olympic M = 16, SD = 0.4; International M = 18.3, SD = 1.6). Informed consent was obtained from the guardians and/or parents of all the gymnasts to participate in the study.

Data Collection

General structure of interview. To obtain developmental and retrospective information regarding the sport involvement of the gymnasts, an in-depth structured interview (Côté et al., 2005) was used. The interviewer requested the information from the gymnasts in a standardized way during interviews that lasted between two and three hours. All the interviews were conducted in English with each of the gymnasts individually. To facilitate the interviews with the Olympic level gymnasts, for whom English was not their mother tongue, a translator was present. Although all of the Olympic gymnasts were fluent in English, they would occasionally ask the translator to clarify the meaning of individual words during the interviews.

The interview procedure for the parents of a sub-sample of the International gymnasts consisted of a modified and abbreviated version of the procedure used with the gymnasts. The parents were primarily asked to recall or estimate the activities, the number of hours spent in practice, quality of training resources, and health of their children during their development as gymnasts.

Detailed structure of interview. The data collection was sectioned into four parts. In part one of the interviews (addressing activities and milestones), the gymnasts were asked to recall their early sporting experiences and how they were introduced to rhythmic gymnastics. They were also asked about ages at which they reached various developmental milestones, such as when they first started training in rhythmic gymnastics, when they spent all their available leisure time on training, when they had to relocate to attend regular training, and the highest ranking that they achieved during the competitive season of each year of their development.

Part two of the interview examined health and training resources. In order to obtain information on the effect of injuries on the performance level, gymnasts were asked if they had ever sustained an injury that had an adverse effect on their performance in rhythmic gymnastics. If an injury was reported, they were asked to describe the nature and duration of this injury. The gymnasts then rated their health for each year of their development on a scale of 0-100%. A rating of 100% corresponded to a year when a gymnast's training and performance had not been hindered by injuries or health problems. Conversely, ratings of 0% corresponded to being completely unable to train and compete during that year. Quality of training resources was also rated on a scale of 0-100%. Gymnasts were asked to rate the training resources on a scale where 100% corresponded to the best possible environment in the world for the training of world-class gymnasts in their sport. A rating of 0% was defined as complete lack of resources.

In part three of the interview, information about the total number of hours spent in practice throughout development and the number of hours spent in various practice activities was collected. Athletes were asked to start at the first year of their participation in the sport and work forward through their career. A number of deliberate practice researchers (e.g., Starkes et al., 1996; Hodges & Starkes, 1996) have recommended that participants be asked to work backwards from the current year when reporting their prior practice to avoid exaggerating their practice estimates. However, according

to Ericsson et al. (1993) as long as both groups started with their first practices there were no bias of group differences for the overestimates of ratings compared to diaries. Therefore, the interview guide was carefully structured to incorporate memory cues in order to minimize recall biases when starting from the athletes' first practice in the sport (Côté et al., 2005).

Athletes were first asked to identify the specific practice activities they engaged in during each training session during each year of their training. All athletes identified the same five practice activities of warm-up, ballet, technique training, routines, and conditioning. Warm-up activities were outlined as activities that included jogging and stretching and were done to prepare the body for other training activities in the practice session. Ballet consisted of a regimented routine of exercises that was designed to improve and refine movements. Technique training consisted of learning new skills that would be used in routines. During technique training, the routines were segmented and gymnasts worked on specific parts of the routine individually. Routine training referred to practicing routines that had been choreographed for competition. Conditioning activities were described as activities designed to improve strength, flexibility, and cardiovascular fitness. To calculate the total number of hours per year, the gymnasts were asked to report the number of hours that they spent in each practice as a whole, as well as how many hours were spent in the five specific practice activities done within these training sessions. The number of hours was then multiplied by the number of practices in one week and then by the number of weeks that they trained that year. Finally, the gymnasts rated the five training activities in terms of physical effort, mental concentration, and fun for their last period of development (i.e., age 16 and older). Each variable was rated on a 0-100% scale with meaningful anchors for each gymnast (Côté et al., 2005).

Data Analysis

The analysis was conducted in four parts, corresponding to the four components of the interview. Part one of the analysis investigated the gymnasts' early activity involvement and performance milestones. Descriptive statistics were used to report the early activities that the gymnasts were involved in, rankings, and other important developmental milestones. T-tests were used to assess statistical differences between Olympic and International gymnasts on the number of activities they were involved in throughout their careers and the attainment of various developmental milestones. To validate these performance reports, results were obtained from the national sporting organization. In addition, official web sites were consulted in order to confirm the gymnasts' reports of their results at various competitions.

An examination of the developmental information reported by the gymnasts on their careers in rhythmic gymnastics revealed four distinct periods of participation for both groups of gymnasts, with the exception of two International gymnasts who started at a later age. The first period, between ages 6 and 8, contained the gymnasts' introduction to the activity and sport of rhythmic gymnastics. From the age of 9 to 12 (Period 2) the

A copy of the interview guide is available upon request from the first author

gymnasts increased the number of training hours with a focus on the development of a solid foundation of sport-specific skills. During this period, the gymnasts were starting to compete at the level of national competition. From the age of 13 to 15 (Period 3) the gymnasts dedicated all of their spare time to training with a goal of winning competitions at the national and international level. The athletes were focused on refinement, with their training consisting largely of repetition of techniques and routines. During the final period at age 16 and older (Period 4), the focus was on maintaining a high level of international performance. The mean number of each variable at each period was used to test interaction and differences between groups (Olympic vs. International) and periods of development. Because some International gymnasts did not get involved in gymnastics before age 9, only three periods (Period 2 = age 9-12; Period 3 = age 13-15; Period 4 = age 16+) were used for the analyses of health/injury and quality of training resources. Gymnasts who did not start gymnastics before age 9 were given a 0 for number of hours training during the first period of development (age 6-8). Therefore, three periods of development were used for the analyses of health and training resources while four periods were used for the analyses of training hours.

Parts two and three of the data analysis were analyzed through two-way ANOVAs with repeated measures across the periods of development. Main effects and interactions were analyzed and subsequent Bonferroni post hoc tests were conducted to determine statistical significance. Part four of the data analysis examined physical effort, mental concentration, and fun of all the activities at age 16. A two-way ANOVA with repeated measures across activities was conducted to identify if there were differences between the two groups and between activities.

All data in the repeated-measures ANOVA's were subjected to Mauchly's test for sphericity. Whenever the Mauchly's sphericity assumption was violated, the ANOVA results were adjusted using the Greenhouse-Geisser correction. Main effects and interactions were analyzed and subsequent Bonferronni post hoc tests were conducted in order to test for differences between conditions. The risk of type-I errors in the post hoc comparisons is controlled by the Bonferroni technique by adjusting the Alpha level based on the number of possible pairwise comparisons. For all results, where interactions were found, error bars are presented on the graphs in order to depict the standard deviation of the cell means.

Results

Activities and Milestones

The Olympic level gymnasts participated in very few other sporting activities over the course of their development. These gymnasts participated in an average of less than two additional activities from age 4 to 16 (M = 1.35, SD = 0.13). From age 8 to 16, one gymnast continued to engage in extra ballet classes outside of her regular gymnastics training session, and one participated in diving lessons at age 16. The International gymnasts showed an increase in the number of activities they engaged in from the ages of 5 (M = 1.17, SD = 0.75) to 9 (M = 3.00, SD = 0.63). They remained involved in an

average of two to three activities until the age of 12, when all of the International gymnasts were engaged solely in rhythmic gymnastics, with the exception of one gymnast who continued to participate in ballet sessions until age 15. An independent samples t-test was used to assess the differences between the Olympic and International gymnasts on the total number of activities they were involved in from age 4 to age 16. Results showed a significant difference t(10) = *5.74*, p = .001 d = 3.31), with the Olympic gymnasts (*M* = 1.31, *SD* = 0.16) involved in significantly fewer activities than the International gymnasts (*M* = 2.34, *SD* = 0.41).

Although the Olympic level gymnasts did not start regular training at a significantly earlier age, they started to compete at the regional level (competitions in their municipality) at a significantly earlier age (*M* = *7.3*, *SD* = 0.8) than the International gymnasts (*M* = 8.8, *SD* = 1.*7* (*t*(10) = 2.58, *p* = .03, *d* = 1.13). Throughout the gymnasts' athletic development, both the Olympic and International groups attained the provincial (competitions combining certain areas of the country), national, and international level at ages that did not significantly differ from each other. Even the ages at which these gymnasts first won a competition at each respective level corresponded closely, with one obvious exception. The Olympic gymnasts won their first international competition at an average age of 15.3 years old, whereas none of the International gymnasts had ever won such a competition.

The Olympic and International gymnasts reported similar ages when they started spending all of their leisure time on their gymnastics training (Olympic, *M* = 11.5, *SD* = 0.5, International, *M* = 12.0, *SD* = 1.4). All of the Olympic gymnasts reported moving to another city to train at a center with the best coaches and in the best facilities at an average age of 13.*7* (*SD* = 1.*37*). No one in the International group moved or relocated to improve their training conditions.

Health/Injury

The rated degree of health/injury was analyzed for the two Groups of gymnasts with a two-way ANOVA with repeated measures for three Periods of development (i.e., Period 2: age 9-12; Period 3: 13-15; and Period 4: 16). The ANOVA results were adjusted using the Greenhouse-Geisser correction. Using this correction, the results revealed significant main effects for Group (*F*(1,20) = 5.14, *p* = .04, η^2 = .28) and Period (*F*(2,20) = 14.43, *p* = .001, ε = .61, η^2 = .18) and no significant interaction between Group and Period. Across Groups, the Olympic gymnasts (*M* = *57*%) rated their health significantly lower than the International gymnasts (*M* = 82%). Bonferroni post hoc tests of the means for the four Periods (six possible pair-wise comparisons of four means, *p* = 0.0083) revealed that the rating of health decreased significantly from Period 2 (*M* = 84%) to both Periods 3 (*M* = 63%) and 4 (*M* = 62%), but Periods 3 and 4 did not differ significantly from each other.

Training Resources

The rated degree of training resources was analyzed for the two Groups of gymnasts with a two-way ANOVA with repeated measures for three Periods of development (i.e., age 9-12; 13-15; 16). The rating of training resources (*M* = 79%) showed no significant interaction between Groups and Periods, nor any significant main effects for Group and Period.

The Quantity of Practice

First, we analyzed the total amount of practice, followed by separate analyses of each type of practice activity (warm-up, ballet, technique, routines and conditioning). The descriptive data used for these analyses are presented in Table 1. We used the number of hours for years in which the person was active.

Average number of hours of practice per year. The average number of hours of practice per year (Table 1) was analyzed for the two groups of gymnasts with a two-way ANOVA with repeated measures for four Periods of development (i.e., age 6-8; 9-12; 13-15; 16). The significant main effects of Group ($F(1,30) = 59.96$ $p = .000$, $\eta^2 = .36$) and Period ($F(3,30) = 32.20$ $p = .000$, $\eta^2 = .30$) were qualified by their significant interaction ($F(3,30) = 6.87$, $p = .001$, $\eta^2 = .07$). The interaction is shown in Figure 1 and suggests a steeper increase in training hours for the Olympic gymnasts than for the International gymnasts. A Bonferroni correction post hoc comparison of the means of Olympic gymnasts' practice at each Period revealed significant increases in the number of practice hours. To keep the risk of Type-I errors at .05 the Bonferroni technique adjusts the alpha to .0018 (i.e., .05 divided by 28—the number of possible pair-wise comparisons of eight means). Amount of practice for the Olympic gymnasts for Period 1 (*M* = 69, *SD* = 35) differed significantly from Periods 3 (*M* = 2093, *SD* = 605) and 4 (*M* = 2609, *SD* = 359), and amount of practice in Period 2 (*M* = 1315, *SD* = 210) was significantly different from Period 4 (*M* = 2609, *SD* = 359). A corresponding analysis of the amount of practice for International gymnasts showed no significant differences between Periods. Overall, the average accumulated number of hours for gymnasts at age 16 was significantly higher ($t(10) = 8.11$, $p. = .000$, $d = 4.68$) for the Olympic Group (*M* = 18835, *SD* = 2936) than for the International gymnasts (*M* = 6686, *SD* = 2198).

Warm-up. The average number of hours of spent in warm-up per year (Table 1) was analyzed for the two Groups of gymnasts with a two-way ANOVA with repeated measures for four Periods of development (i.e., age 6-8; 9-12; 13-15; 16). The results showed neither significant main effects for Group or Period, nor any interaction. Therefore, both Olympic and International gymnasts engaged in similar numbers of hours (*M* = 102.6 hours, *SD* = 33.3; Table 1) in warm-up per year across all Periods of development.

Ballet. The average number of hours of ballet per year (Table 1) was analyzed for the two Groups of gymnasts with a two-way ANOVA with repeated measures for four Periods of development. The results showed both significant main effects of Group ($F(1,30) = 37.29$, $p = 0.000$, $\eta^2 = .94$) and Period ($F(3,30) = 8.19$, $p = 0.000$, $\eta^2 = .13$), but no reliable interaction. The Olympic gymnasts (*M* = 358; *SD* = 111) engaged

Table 1. Mean and Standard Deviation for # hours in training activities per periods.

		Olympic				International			
Period		**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Total practice	M	693	1315	2093	2609	135	547	792	859
	SD	354	210	605	359	261	151	304	623
Warm-up	M	111	147	105	95	31	109	124	99
	SD	86	30	27	32	66	67	65	79
Ballet	M	199	388	388	456	24	43	76	102
	SD	184	127	102	140	41	23	65	119
Technique	M	140	275	415	529	28	125	148	153
	SD	80	50	120	183	52	57	40	101
Routines	M	156	349	1007	1311	42	229	394	435
	SD	78	128	578	514	81	137	278	391
Conditioning	M	87	156	177	219	10	40	51	70
	SD	111	129	57	52	22	37	29	46

Note. Period 1 = age 6-8; period 2 = age 9-12; period 3 = 13-15; period 4 = age 16

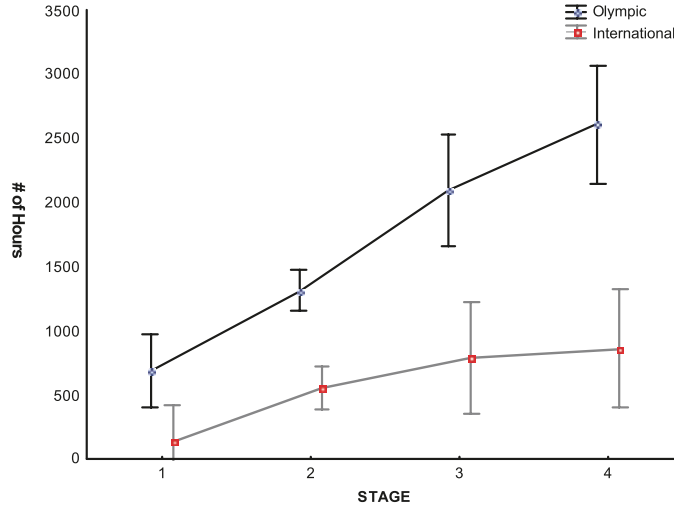

Figure 1. Total practice hours by periods of development for the Olympic and International gymnasts.

in significantly more hours per year in ballet than the International gymnasts (M = 61, SD = 35). A post-hoc analysis using the Bonferroni method (p = 0.0083) to examine the different Periods showed that the number of hours spent in ballet increased significantly from Period 1 (M = 112, SD = 124) to Periods 2 (M = 215, SD = 244), 3 (M = 232, SD = 221), and 4 (M = 279, SD = 250). Periods 2, 3, and 4 were not significantly different from each other.

Technique training. The average number of hours of technique training per year (Table 1) was analyzed for the two Groups of gymnasts with a two-way ANOVA with

repeated measures for four Periods of development (i.e., age 6-8; 9-12; 13-15; 16). Using the Greenhouse-Geisser correction, the results showed significant main effects of both Group ($F(1,30) = 57.46$, $p = 0.000$, $\eta^2 = .55$) and Period ($F(3,30) = 16.72$, $p = .000$, $\varepsilon = .57$, $\eta^2 = .40$) that were qualified by their interaction ($F(3,30) = 4.82$, $p = .03$, $\varepsilon = .57$, $\eta^2 = .08$). The interaction is shown in Figure 2 and suggests a steeper increase in technique training hours for the Olympic gymnasts, compared to the International gymnasts. Pairwise comparisons of all means (Bonferroni adjusted alpha of $p < .0018$) revealed no differences between any of the Periods for the International gymnasts. The same analysis revealed that technical training of Olympic gymnasts increased significantly from Period 1 ($M = 140$, $SD = 80$) to Periods 3 ($M = 415$, $SD = 120$) and 4 ($M = 529$, $SD = 183$), but Periods 3 and 4 did not differ significantly from each other. Furthermore, the amount of technical training increased from Period 2 ($M = 275$, $SD = 50$) to Period 4 ($M = 529$, $SD = 183$).

Training of routines. The average number of hours of routines per year (Table 1) was analyzed for the two Groups of gymnasts with a two-way ANOVA with repeated measures for four Periods of development (i.e., age 6-8; 9-12; 13-15; 16). Using the Greenhouse-Geisser correction, the results showed significant main effects for both Group ($F(1,30) = 9.79$, $p = 0.01$, $\eta^2 = .28$) and Period ($F(3,30) = 21.90$ $p = .000$, $\varepsilon = .48$, $\eta^2 = .58$) that were qualified by their significant interaction ($F(3,30) = 6.11$, $p = 0.02$, $\varepsilon = .48$, $\eta^2 = .10$). This interaction is illustrated in Figure 3 and suggested a steeper increase for Olympic gymnasts compared to the International gymnasts for the corresponding Periods. Pair-wise comparisons (Bonferroni adjusted alpha of $p < .0018$) revealed no reliable differences in the amount of the routine training for the four Periods for the International gymnasts. In contrast, the amount of routine training increased significantly for the Olympic gymnasts for Periods 1 ($M = 156$, $SD = 78$) and 2 ($M = 349$, $SD = 128$) to Period 4 ($M = 1311$, $SD = 514$). The amount of routine training also increased significantly from Period 1 ($M = 156$, $SD = 78$) to Period 3 ($M = 1007$, $SD = 578$).

Conditioning. The average number of hours of conditioning per year (Table 1) was analyzed for the two Groups of gymnasts with a two-way ANOVA with repeated measures for four Periods of development (i.e., age 6-8; 9-12; 13-15; 16). Using the Greenhouse-Geisser correction, the results showed significant main effects of both Group ($F(1,30) = 15.77$, $p = 0.003$, $\eta^2 = .44$) and Period ($F(3,30) = 5.98$, $\varepsilon = .47$, $p = 0.02$, $\eta^2 = .15$), but no significant interaction. The Olympic gymnasts ($M = 160$, $SD = 55$) engaged in significantly more hours per year in conditioning than the International gymnasts ($M = 43$, $SD = 25$). Bonferroni pair-wise comparisons of the means for all Periods (adjusted alpha is 0.0083) showed that conditioning increased from Period 1 ($M = 49$, $SD = 54$) to Periods 3 ($M = 114$, $SD = 89$) and 4 ($M = 144$, $SD = 105$), which did not differ significantly from each other.

Ratings of Qualities of Different Practice Activities

Gymnasts rated three aspects (fun, physical effort, and mental concentration) for each of the five practice activities (warm up, ballet, technique, routines, and conditioning) for the

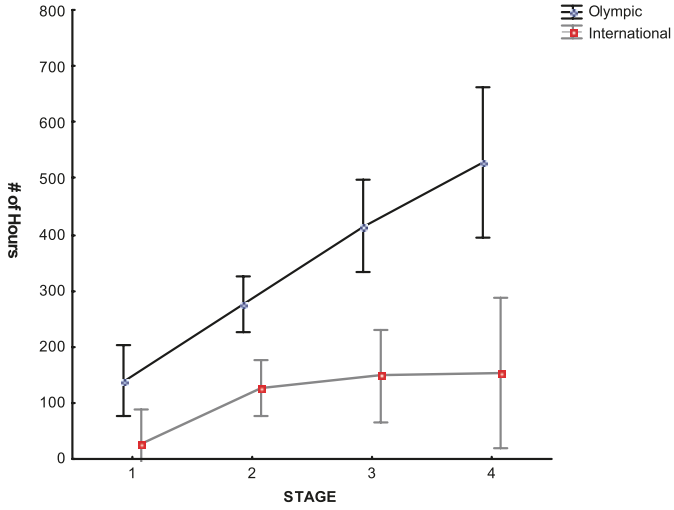

Figure 2. Hours in technique training by periods of development for the Olympic and International gymnasts.

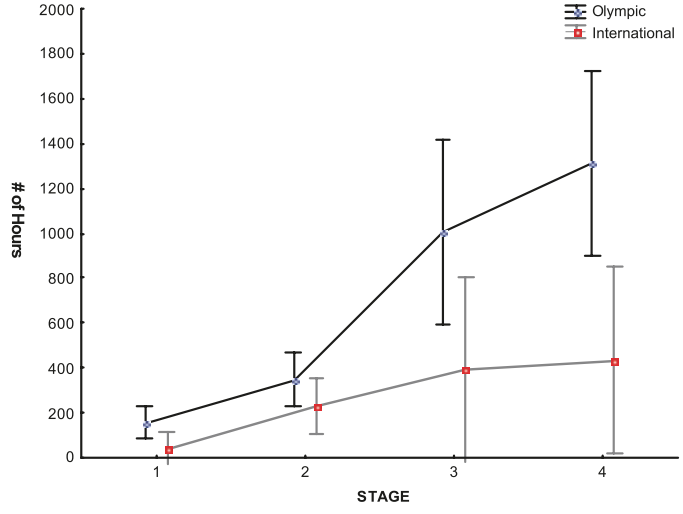

Figure 3. Hours in routine training by periods of development for the Olympic and International gymnasts.

last period of development (i.e., age 16 and older). The mean ratings of each practice activity for the Olympic and International gymnasts are reported in Table 2.

Physical effort. The rated physical effort (Table 2) was analyzed for the two Groups of gymnasts with a two-way ANOVA with repeated measures for five Practice activities. Using the Greenhouse-Geisser correction, the results showed a significant main effect of

Table 2. Percentage rating of effort, mental concentration, and fun for training activities

		Olympic			International		
		Effort	**Mental**	**Fun**	**Effort**	**Mental**	**Fun**
Warm-Up	**M**	62	43	67	78	61	66
	SD	37	38	29	9	14	31
Ballet	**M**	57	45	18	64	58	38
	SD	15	26	23	58	19	27
Technique	**M**	77	73	47	86	83	78
	SD	16	24	22	14	13	9
Routines	**M**	83	85	39	88	85	76
	SD	8	17	37	10	14	14
Conditioning	**M**	72	64	10	70	48	57
	SD	21	28	13	18	19	32

Practice activity ($F(4,40) = 4.20$, $\varepsilon = .59$, $p = .02$, $\eta^2 = .26$) but no significant main effect of Group nor an interaction between Group and Practice activity. Pair-wise Bonferroni comparisons of the mean ratings for each Practice activity (adjusted alpha is 0.0083) revealed only two significant differences between means. Both types of training, namely routine ($M = 85\%$, $SD = 4\%$) and technique ($M = 81\%$, $SD = 6\%$) were judged to require more physical effort than ballet ($M = 60\%$, $SD = 5\%$).

Concentration. The rated concentration (Table 2) was analyzed for the two Groups of gymnasts with a two-way ANOVA with repeated measures for five Practice activities. Using the Greenhouse-Geisser correction, the results showed a significant main effect of Practice activity ($F(4,40) = 7.24$ $p = .000$, $\varepsilon = .74$, $\eta^2 = .42$) but no significant main effect of Group nor an interaction between Group and Practice activity. Pairwise Bonferroni comparisons of the mean ratings for each Practice activity (adjusted alpha is 0.0083) revealed that routines ($M = 85\%$, $SD = 0$) were judged to require significantly more concentration than warm-up ($M = 52\%$, $SD = 23$), ballet ($M = 52\%$, $SD = 9$), and conditioning ($M = 56\%$, $SD = 11$). Similarly, technique ($M = 78\%$, $SD = 7$) was judged to require significantly more concentration than ballet ($M = 52\%$, $SD = 23$) and warm-up ($M = 52\%$, $SD = 23$).

Fun. The rated fun (Table 2) was analyzed for the two Groups of gymnasts with a two-way ANOVA with repeated measures for five Practice activities. Using the Greenhouse-Geisser correction, the results showed significant main effects of Practice activity ($F(4,40) = 8.79$, $p = .000$, $\varepsilon = .82$, $\eta^2 = .32$) and group ($F(1,40) = 6.95$, $p = .02$, $\eta^2 = .23$) but no significant interactions between Group and Practice activity. The Olympic gymnasts ($M = 36\%$, $SD = 23\%$) reported significantly less fun than the International gymnasts ($M = 63\%$, $SD = 16\%$). Pairwise, Bonferroni comparisons of all the means for each Practice activity (adjusted alpha is 0.0083) revealed that ballet ($M = 28\%$, SD = 14%) was judged to be significantly less fun than warm-up ($M = 66\%$, $SD = 1\%$),

technique (*M* = 63%, *SD* = 22%), and routine (*M* = 58%, *SD* = 26%). Furthermore, conditioning (*M* = 33%, *SD* = 33%) was rated to be significantly less fun than technique (*M* = 62%, *SD* = 22%) and warm-up (*M* = 66%, *SD* = 1%).

Validity of Structured Interview

To validate the first part of the interview, a sub-sample of parents (*n* = 4) was also interviewed to collect independent information to provide an assessment of the validity of the responses given by the gymnasts. The international gymnasts' parents interviewed for this validation process constituted a convenience sample, because they were easily accessible living in the same household as the international gymnasts. By contrast, the Olympic gymnasts' parents lived in different areas around the country and, thus, it was not possible within the scope of the current project to interview each parent.

The percentage of agreement between each gymnast and parent was provided to further validate the gymnasts' responses. Parents were asked independently to report the number of activities that their children engaged in throughout their development. The general formula for computing reliability was first to compute the number of activities that both the parent and the gymnast reported and divide that number by the total number of activities. This number was then multiplied by 100 to provide a percentage of agreement. The percent agreement for the four parent-child pairs was 100%, 67%, 100%, and 83%. The average percentage of agreement on the number of activities engaged in was 88% (*SD* = 16%). Secondly, these four parents independently provided the same information about their children, with 100% agreement regarding the total number of years of involvement in the sport.

The gymnasts'-reported information on their performance careers was also validated through an examination of the web sites of the national and international gymnastics federations. The official results posted on these websites were compared to the gymnasts' reports. This validation process revealed a 100% agreement.

To validate the health/injury rating, four parents were asked independently to report the injuries of their children. Similar to the percentage of agreement for activities computed above, the number and type of injuries reported by both parent and child was divided by the total number of injuries reported. The percent of agreement for each parent-child pair was 80%, 83%, 50%, and 100%. The average percentage of agreement of the four parent-child pairs on report of injuries was 78% (*SD* = 21%).

In order to validate the reported practice hours, the parents were asked to estimate the number of hours their children engaged in practice during each year of their participation in gymnastics. Practice for Period 1 was not included in these analyses because three of the four gymnasts started at nine years of age—after the end of Period 1. The percentage of agreement between parent and child was 87%, 87%, 92%, and 88%. The average percentage of agreement of the four parent-child pairs for Periods 2, 3, and 4 was 89% (*SD* = 3%) for the number of hours spent in practice.

Discussion

The present study has provided insight into the development of rhythmic gymnastics at the most elite level and helped to further the understanding of how to assess sport expertise development using retrospective interview methods. A limitation of this study was the use of retrospective methods, with their associated problematic issues of participants recalling past information. However, drawing on Flanagan's (1954) pioneering work on eliciting recall of critical incidents, our interview procedure (Côté et al., 2005) was designed to probe individuals to answer interview questions based on recall of past episodic experiences. In this paper we reviewed the evidence for the superior validity of these retrospective reports and how these types of reports are more accurate and reliable than when participants are forced to infer and reconstruct answers to general questions (see also Ericsson & Simon, 1993). Furthermore, the interview data obtained were selected to permit validation. The data collected from a sample of participants were validated by comparing them to independent interviews with parents. Similarly, the reported information of all participants was successfully matched against public information about the participants' careers.

The rhythmic gymnasts in both the Olympic and International groups attained many of the developmental milestones at remarkably similar ages. The average ages of Olympic gymnasts appeared to be consistently younger than those of the International gymnasts. However, statistically significant differences were found for only three milestones. The most obvious difference between the groups was that only the Olympic gymnasts ever won or placed among the top three finishers at international competitions. In addition, most of the Olympic gymnasts moved away at around age 13 to a different geographical region in order to train with the best coaches in the best training environments, which is consistent with Hodges and Starkes' (1996) findings in wrestling. Finally, the Olympic gymnasts started to compete at the regional level significantly earlier than the International gymnasts.

The early developmental differences that were observed before the Olympic gymnasts moved to their national training center are particularly compelling, as they cannot be explained by a unique training environment with its particular coaches. Both Olympic and International gymnasts trained at different gymnastics clubs in the early periods of their development before joining the elite club in their country. However, Olympic gymnasts engaged in fewer activities during their development than the International gymnasts, and in general both groups of gymnasts engaged in relatively few other activities before the age of twelve, when they became solely engaged in rhythmic gymnastics.

This pattern of results differs from the developmental pattern proposed by Côté and colleagues (Côté, 1999; Côté et al., 2003; Côté & Hay, 2002). These studies evaluated hypotheses that in order to develop successfully to high levels of performance, children should engage in a variety of activities before specializing and investing their energies in a single sport. These periods were later validated in the team sports of basketball, netball, field hockey (Baker et al., 2003a; 2003b), ice hockey (Soberlak & Côté, 2003), and triathlon (Baker et al., 2005). It was shown in these studies that team sport athletes typically invest from ages 15 to 18 and reach peak levels of performance in their

twenties. In contrast, the athletes in the present study did not sample a wide variety of activities before they invested in rhythmic gymnastics, thus failing to follow the same developmental sequence as the team-sport athletes and triathletes studied by Côté and colleagues (Baker et al., 2003a; Baker et al., 2005; Soberlak & Côté, 2003). In a study Ward et al. (2004) assessed the contribution of domain-specific practice (in particular "deliberate" team practice), playful activities, and match-play in the development of nine groups of age-matched elite and sub-elite soccer players (ages 9-18). They found that the amount of domain-specific practice explained "56 percept of the variance between skill groups, increasing to 76 percent for the oldest groups" (Ward et al., 2004, p. 241). Their findings showed that the duration for playful activities and involvement in non-sport specific activities were higher for the sub-elite players than the elite players, thus showing the opposite pattern from that found by Côté and his colleagues, which is consistent with the pattern observed in the current study.

Rhythmic gymnasts are competing at the international level as early as 12 years of age, with a first place finish at the international level as early as age 15. This early age of high-level performance stresses the need for athletes to focus on rhythmic gymnastics very early in their development. Elite rhythmic gymnasts engage in long hours of practice at younger ages than sub-elite gymnasts. Thus, the opportunity to take part in other activities is limited by the commitment to ballet and gymnastics.

This early start of intense specialized practice among our rhythmic gymnasts raises ethical issues and associated risks to this type of youth sport specialization (Wiersma, 2000). Wiersma stated that specializing too early in one activity could have a negative impact on the sociological and psychological development of the athlete, which in turn could be the reason athletes drop out of sport. According to Gould and Udry (1996), sport specialization in children at a young age can lead to increases in training, excessive repetition, and high expectations of performance from the parents, coaches, and the athletes themselves. These types of increased demands may explain the lower level of "fun" experienced by the Olympic gymnasts in the present study. Alternatively, the Olympic gymnasts may have engaged in their training activities (technique, conditioning, and ballet) with greater concentration and effort, consistent with predictions from deliberate practice (Ericsson, 1996).

Furthermore, the Olympic gymnasts' reported lower health/more injuries than the International gymnasts, and both groups experienced a decrease in health ratings in the later periods of their participation. Interestingly, the Olympic gymnasts showed a steeper increase in the total number of hours spent in training compared to the International gymnasts in Periods 3 and 4. It is possible, and even likely, that the higher training volume and the more technically challenging routines of Olympic gymnasts' increases risks for injury, thus leading to reduced health ratings (Kellman, 2002). The injuries reported by the gymnasts in our study were categorized as overuse injuries (i.e., stress fractures, joint strain). Overuse injuries would be expected as a potential negative outcome of continued repetitive stress placed on the body during extended training of technique and routines. However, the reported health of the gymnasts did not negatively affect their competitive performance, although any effects of reported injuries may have been offset

by the superior quality of essential health care and medical treatments that was provided to ensure continued involvement for the Olympic level gymnasts (Norris & Smith, 2002). These findings motivate a better understanding of how the specific components of training affect the gymnasts' health and how adverse training effects should not only be alleviated by health care resources, but also how modification of quality and quantity of training could prevent the emergence of the injuries and health problems. Therefore, when designing models of sport development in rhythmic gymnastics where elite gymnasts engage in intense training at an early age, it is crucial that coaches be sensitive to these health risks and design effective practice activities for the right periods of development. Future research in this area should examine the health of the Olympic gymnasts at the termination of their careers in order to develop a greater understanding of the ethical issues surrounding the amount of training at a highly intense level and how it affects the gymnasts' adult lives following the end of their participation in competitive sports.

Our retrospective methods revealed developmental trends and group differences in the amount of engagement in most practice activities. However, the duration of warm-up activities designed to prepare the body and mind for deliberate practice showed no reliable developmental trends or differences between the International and Olympic gymnasts. The duration of other activities, such as "ballet" and "conditioning," designed to change fundamental aspects of movements and the body, such as strength of muscles and efficiency of the cardio-vascular system, was significantly longer for Olympic gymnasts than for the International gymnasts. Importantly, Olympic athletes, in contrast to International athletes, reported an increase in the number of practice hours devoted to routines and techniques during the later periods of their development.

Hence, the principal differences between the Olympic and International gymnasts' training concerned those practice activities, routine and technique, which approximate most closely the conditions and demands of their performance at competitions. This finding is similar to past research on deliberate practice in sport where individuals reported spending more time in activities that are most relevant and closely related to the actual performance (Baker et al., 2003b; Ericsson, 2003; Hodge & Deakin, 1998; Hodges & Starkes, 1996; Starkes et al., 1996; Young & Salmela, 2002).

Previous studies have found that athletes overestimate the hours of active training in both music (Ericsson et al., 1993) and figure skating (Deakin, 2001). Deakin (2001) showed that figure skaters were accurate in reporting the number of scheduled practice hours, though the actual practice time may be 13-46% lower than that reported. This "active time" relates to the times during which the athletes were actually performing skills, as opposed to taking a rest period between practice activities. Rhythmic gymnastics is similar to figure skating in terms of the technique and routine training, which are characterized by an intense few minutes of physical performance followed by a recovery period (rest). Although this recovery period is not characterized as being "active training," athletes in sports that require a short burst of activity need a recovery period in order to be able to perform the next skill. The present study was mainly concerned with the issue of obtaining an estimate of the total duration of the various activities rather than estimating the active training time. Future studies in rhythmic gymnastics should examine "active

training time" and length of recovery periods in training. However, we would expect a high correlation between total time and active training time for a given training activity, at least for expert performers, and thus this distinction is unlikely to account for our differences between the Olympic and International gymnasts' training history.

Olympic gymnasts spent considerably more time than International gymnasts on two training activities during their development across all four periods, namely "ballet" and "conditioning." These two activities were given significantly lower ratings of fun by both groups of gymnasts. While the Olympic gymnasts gave lower ratings for all activities than the International gymnasts, their ratings of fun for "ballet" and "conditioning" were remarkably low - 18% and 10 % respectively. More accomplished gymnasts have been found to enjoy practice less than less accomplished gymnasts by other investigators. Hume et al. (1994) reported a negative correlation ($r = -0.32$, $p < .01$) between rated enjoyment of training sessions and attained level of skill in sub-elite rhythmic gymnastics. It is likely that the Olympic gymnasts are more motivated by the desirable consequences from engaging in those practice activities that lead to improvements in performance, a finding consistent with the original characteristics observed for deliberate practice (Ericsson et al., 1993).

A retrospective interview procedure (Côté et al., 2005) allowed us to successfully track the development of two groups of elite performers in rhythmic gymnastics and identify differences in environments and practice that were sufficient to explain the differences in attained performance. There are large differences in the development of expert performance and the characteristics of relevant training activities across different domains of sports. Consequently, it is important to consider the age at which peak performance is reached before generalizing and applying the results of the present study to other activity domains. The findings of the current study could be of particular interest to individuals involved in the development of expert performers in sports where performance peaks at an early age, most often before full maturation is completed. These sports are often practiced by women and have an artistic component to performance such as figure skating, ballet, artistic gymnastics, and dance.

In conclusion, the differences in the developmental history between athletes at the highest level of elite performance, namely between Olympic and International gymnasts, reveal earlier specialization with increased hours engaged in activities that are not inherently enjoyable (cf. ballet and conditioning). This type of training is likely important as it provides a movement foundation for rhythmic gymnastics. Subsequently, gymnasts must increase the hours they spend in activities that are most closely related to the actual performance in the later years of participation (cf. routine and technique training) in order to attain international successes in rhythmic gymnastics.

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