Successful talent development in popular game sports in Switzerland: The case of ice hockey

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Abstract

There is continuing discussion in talent research on the best approach to developing sporting expertise through learning activities during early sport participation. Among other concepts, the specialized sampling model describes a pathway between early specialization and early sampling and yields promising results in Swiss football. As successful constellations of early sport participation might be affected by sport-specific constraints (e.g., age of peak performance, selection pressure, and physiological/psychological requirements), other popular game sports may show similar promising pathways. This study investigates whether ice hockey, another popular game sport in Switzerland, shows similar successful constellations of early sport participation. A sample of 98 former Swiss junior national team players born between 1984 and 1994 reported on early sport participation through a retrospective questionnaire. Using the person-oriented Linking of Clusters after removal of a Residue (LICUR) method, volumes of in-club practice, free play, and activities besides ice hockey until 12 years of age were analyzed, along with player's age at initial club participation. The results indicate that ice hockey enthusiasts with the most free play and above-average in-club practice had a greater chance of reaching professional level compared to other groups. This implies that high domain specificity with varied sampling experiences is the most promising approach to developing sporting expertise in ice hockey. As similar results were previously found in Swiss football, comparable sport-specific constraints might indeed require similar constellations of learning activities during early sport participation. Therefore, in popular game sports in Switzerland, the specialized sampling model seems to be most promising.

Keywords: Developmental model of sport participation, free play, specialised sampling model, team sport

Introduction

Talent research is thoroughly investigating how talents should be supported to ensure optimal development of their abilities until they will reach sporting expertise. The optimization of this process has been especially researched in recent years, and several frameworks for successful talent promotion have been developed.[1-6] Within these talent development models, several factors have been identified as relevant to developing sporting expertise[7] and they all highlight the importance of early sport participation in childhood for later expertise.[3,4] However, talent research continues to debate which learning activities are the most promising during early sport participation.[8,9]

Long-running interest in the specific design of promising learning activities toward developing sporting expertise has evolved into the debate between early specialization[4] and early sampling.[3] Researchers differentiated two opposing approaches in early sport participation: athletes either follow the early specialization approach (i.e., the deliberate practice framework)[3] or the early sampling approach (i.e., the elite performance through sampling pathway from the Developmental Model of Sport Participation).[4] Thus, a unidimensional construct of early sport participation was assumed. The common debate supposes that to develop sporting expertise, athletes have to either specialize or sample.

The unidimensionality of specializing and sampling has been criticized. Researchers usually neglect that within developmental pathways of early sport participation there are two intertwined dimensions: domain specificity and performance orientation.[10,11] Domain specificity describes the degree of congruence between the biomechanical, physiological, and psychological characteristics of learning activities and the required characteristics in the primary sport domain.[12] Focusing on a single sport domain has a high value of domain specificity, whereas engaging in several kinds of sports has a low value of domain specificity. Performance orientation is best described by the characteristics of the learning activities (e.g., degrees of goal setting, monitoring, correction, physical and psychological engagement). A highly structured, coach-led activity (i.e., practice) has a high value of performance orientation,

whereas fun-oriented learning activities without supervision (i.e., play) have a low value of performance orientation.

The dichotomous character of the initial approaches in early sport participation is also revealed in the reconceptualized two-dimensional framework (Figure 1). Proponents of the early specialization approach[4] argue that, after a short initiation/orientation phase, the early selection of a primary sport in childhood is vital. Therefore, learning activities with high domain specificity (focusing on one sport domain) should be the primary source of sporting development for young talents. Moreover, the selected activities should involve a vast amount of systematic and structured practice, meaning that performance orientation is also high. Derived from the power law of practice[13], early specialization assumes that the more an individual undertakes targeted, sport-specific training, the earlier it masters sport-specific skills and, therefore, the higher its possibility of developing expertise.

Contrary to this view, Côté et al.[14] describe the early sampling approach. They argue that children should explore several sport domains, engage in poly-sportive activities, and thus maintain a low domain specificity before deciding on a single sport domain around 12 years of age. They argue that informal, unorganized, and enjoyable play (e.g., street football), which is associated with a low performance orientation, should be pursued along with early sampling. The early sampling approach posits that early specialization within one sport domain is not appropriate for developing sporting expertise because of higher risk of overuse, potentially leading to injuries or burn-out.[15,16,17] Proponents assume that enjoyment in informal sport settings is a source of high intrinsic motivation and leads to longer continuation in the sport.[18] Moreover, transfer effects between sports are expected to occur, which is assumed to contribute to developing sporting expertise.[14,19,20]

There is empirical evidence for both early specialization (with high values in domain specificity and performance orientation) and early sampling (with low values in domain specificity and performance orientation) as promising approaches for developing sporting expertise. For example, the early specialization approach has been found to be valid for gymnastics[21] and figure skating[22], while the early sampling approach has shown to be

successful for triathlon[23] and rowing.[3] For a long time, scholars dichotomized this two-dimensional construct of sport participation in childhood, meaning that young talents either specialize in one sport domain and engage in structured practice or sample among several sport domains and conduct fun-oriented play.[24] Yet, for many sports, this conceptualization of a dichotomous construct between early specialization and early sampling has been found to be unsuitable.[25] Therefore, we should instead consider these two dimensions as independent continua as it is possible to specialize in one sport domain (high value of domain specificity) while sampling different experiences in different settings and also varying between play and practice (from low to high values of performance orientation).[12,26]

--- Insert Figure 1 about here ---

The last decade has produced an increasing amount of empirical evidence that the most successful approaches to early sport participation may range between the poles of the early specialization (high values in both dimensions) and early sampling pathways (low values in both dimensions).[12,25,27] For example, the early engagement hypothesis[25] combines high amounts of play in the primary sport with medium amounts of practice in the primary sport and a low to medium volume of engagement in other sports.[28] This predominant exertion in the primary sport (high domain specificity) with both high and low performance orientation (practice and play), supplemented by a minor amount of learning activities in other sport domains, was recently redefined as the early majority engagement approach.[27] Further, the specialized sampling model of Sieghartsleitner et al.[12] stresses the importance of high domain specificity (i.e., focusing on one sport domain), involving various experiences with different degrees of performance orientation across the practice–play continuum within this domain (figure 1).

All the above mentioned approaches have been shown to be successful in promoting sporting expertise in certain cases. However, it is unlikely that any one of them is generally valid across all sporting contexts, as other influencing factors determine which approach to early sport participation might be successful. It is reasonable to assume that a range of unique,

sport- and context-specific constraints shape the development of sporting expertise[29], such that different approaches are needed to succeed in different circumstances. The literature identifies at least three different constraints for each sport domain: 1) age of peak performance, 2) performance density or selection pressure, and 3) the physiological and psychological requirements.[28,30]

The age of peak performance might determine the pressure for a young talent to focus on a single sport domain (domain specificity) as well as the characteristics of the learning activities (performance orientation).[28] It is plausible that the earlier the age of peak performance, the stronger the need for young talents to follow the early specialization approach, meaning that they should focus on one single sport domain and undertake high amounts of systematic, structured, coach-led learning activities such as practice. At the other end of the scale, in sports with a high age of peak performance, there is no need for an early focus as described in the early specialization approach. In fact, young athletes should arguably examine different types of sport at the age of early sport participation in order to develop sporting expertise. By doing so, they can benefit from transfer effects from other sport domains after deciding on their favorite sport.[19]

Regarding performance density or selection pressure, it can be assumed that higher selection pressure increases the need to follow the early specialization approach.[28] The larger the number of potential talents engaging in a sport, the harder it is to be successful later. If more children are participating in a sport, then this likely increases the number of potential talents. Therefore, a sport with high selection pressure requires high domain specificity and performance orientation at an earlier age in order to master the required skill set for developing sporting expertise.

Different sport domains have different physiological and psychological requirements. Game sports, for instance, require a high level of technical and tactical knowledge and skills. Consequently, these sport domains might require an earlier focus on the early specialization approach compared to endurance-focused sports like triathlon or rowing. Contrary, sports like

gymnastics require high technical skills and thus structured and purposeful practice might start earlier compared to game sports.[21]

These sport-specific constraints are partially determined by societal factors such as the importance and relevance of a sport within a country.[31] These societal factors (e.g., popularity) are reflected in the number of participants in a specific sport domain, which may, for example, affect the selection pressure of the respective sport. In addition, we might assume that two different sports with similar constraints are likely to have similar constellations of successful approaches to early sport participation.[28,30]

Regarding the context of Swiss sport, empirical studies on Swiss football[12,32] have found promising results from the specialized sampling model (i.e., specializing in one sport by sampling various experiences through different settings within this domain) as the most successful early sport participation pathway for developing sporting expertise. Based on the aforementioned hypothesis that sports with similar sport-specific constraints and popularity should reveal similar successful early sport participation pathways, it can be assumed that sports in Switzerland with similar constraints as football could reveal similar successful early sport participation pathways. In Switzerland, the most similar sport to football – showing comparable characteristics in age of peak performance, selection pressure, and physiological/psychological requirements – is ice hockey. There have been only few quantitative studies of early sport participation in ice hockey. Pelletier and Lemoyne[33] investigated the impact of early sport specialization on the amount of hockey-specific und unspecific training activities among adolescent hockey players. They found that a high manifestation of early specialization leads to higher levels of “in-season” and “off-season” physical activities. However, their study does not consider how early sport participation relates to the development of sporting expertise in adult ice hockey. Mosher et al.[34] recently compared early specializers and early samplers in ice hockey and reported that early specializers are more likely to play at highest level at 12 years of age. Again, there was no focus on early sport participation and the development of sporting expertise. In summary, both studies show differences in adolescent hockey players considering early sport participation up to 12 years

of age, but neither measured early sport participation and adult expertise. Hence, our study is the first to consider both aspects within a quantitative study. Specifically, this study investigates the following research question: Which constellations of early sport participation in ice hockey up to 12 years of age show most promise for developing sporting expertise?

Materials and Methods

Sample and study design

Swiss ice hockey players born between 1984 and 1994 were considered for this study. Data were collected through an online survey in 2018. The lower bound of 24 years of age was chosen as an approximate assurance that players had reached their final level of adult performance. The upper bound was selected due to sample-based considerations regarding sample size and age heterogeneity: for example, being a decade older may slightly change the mechanisms of early sport participation. Additionally, players born before 1984 were excluded to assure the reliability of recall data. Players had to have been selected at least once for the U16 junior national team, which means that they once belonged to a rather homogeneous group of the best youth players in Switzerland. The entire population of players fulfilling both criteria numbered 488. After excluding incomplete questionnaires, the study sample contained 98 players (M_{age} = 27.32 years, SD_{age} = 2.6; valid response rate: 20.1%). By using *t*-test, the study sample was compared to the entire population of our inclusion criteria based on the year of birth and performance in adulthood (the performance criterion is outlined in the next chapter). The results of the *t*-tests showed no significant difference for the performance criterion ($t(486) = -1.27$, $p = .207$). However, there is a significant difference for the age ($t(486) = 2.01$, $p = .046$). On average, our sample was younger (M_{age} = 27.32 years) than the entire population (M_{age}= 28.03 years). Based on these results, we can assume that the study sample is representative for the entire population fulfilling the inclusion criteria (born between 1984 and 1994; once selected for U16 junior national team) regarding the performance criterion. However, as there are other performance-related factors (e.g., first age of sport participation, place of residence, relative age) or socio-demographic aspects (e.g.,

education level, relevance of sport within the family), we cannot assume that the study sample was fully representative of the entire population.

The current investigation aimed to capture various factors of early sport participation by applying a longitudinal retrospective research design. Factors of early sport participation of each player from age 0 to 12 were assessed, which covers and summarizes a substantial period of a player's athletic career and is in line with previous conceptualization of the phase of early sport participation.[3] Therefore, it was only possible to collect valid data on events that were remembered sufficiently well, such as volume of training.[35] The validity and reliability of recalled sport participation over short periods of time (i.e., 5 years) have been shown to be relatively high.[36,37] The current study asked players to remember events that occurred 14 to 20 years earlier. To the best of our knowledge, no prior study has analyzed recall data on training after such a long elapse of time. However, Hopwood[38] investigated the development history of athletes in a retrospective manner with a timespan averaging 9 to 15 years in the past, which is similar to the current study. Her study showed that athletes' recall of starting age in different settings of sport participation (in-club practice in primary sport, free play in primary sport, other sport domains) had mostly good validity similar to the recall of parents and retest-reliability. Furthermore, recall of hours of participation was shown to have good validity and retest-reliability for supervised practice.[38] However, only moderate to poor validity and retest-reliability was found by Hopwood[38] for hours of participation in free play and other sport domains. Therefore, for the current study, it is uncertain whether hours of participation in free play and other sport domains before the age of 12 are reliably recalled.

Accordingly, we concentrated particularly on ensuring that participants were able to correctly recall their training activities. Participants were able to pause the online survey to verify their answers with other persons (e.g., parents, former coaches). Furthermore, we asked participants to double check their data against training logs and advised them to retrieve early-career information from eliteprospects.com, which summarizes all official data of ice hockey players around the globe. Finally, the current study was part of a larger investigation of hockey talents' developmental pathway, focused on early sport participation but also other sport

participation events (e.g., milestones, injuries, competitions), educational and vocational training, and other environmental facets of talent development (e.g., familial sport activities). This context might have helped participants to accurately recall information as they could validate their answers across a broader range of information, which Hopwood[38] showed to be well recalled and demonstrate good validity and reliability (e.g., milestones, injuries, support). The study received approval from the Ethics Committee of the Faculty of Human Sciences of the University of Bern, and all players gave their written informed consent to participate.

Operationalisation and data collection

We identified four variables determining early sport participation up to 12 years of age, based on earlier studies.[12,32,36,39,40] These were: (1) volume of organized in-club ice hockey practice, (2) volume of free play within hockey, (3) volume of other sport activities, and (4) age at first ice hockey club participation. We asked participants to report the volumes of all sporting activities in hours per week at any age since entering the sport. These values were then added up to a total number of hours up to and including 12 years of age.

In-club practice consists of all learning activities (e.g., training) within an ice hockey club (or with an instructor). By contrast, free play describes any ice hockey or hockey-like activity (such as floorball, inline hockey, free ice skating, and playing street hockey with neighborhood children) outside the club and without supervision, which is in line with previous research.[12] Other sporting activities (i.e., poly-sportive activities) besides ice hockey were reported regardless of organizational structure. The age at first ice hockey club participation marks the entrance into organized ice hockey.

The performance criterion for adult performance level consisted of the number of games a participant played at a professional performance level up to 24 years of age. Playing at least 100 games in the first- and/or second-highest league in Switzerland was necessary to qualify for professional ice hockey status. Playing less than 100 games corresponds to the non-professional performance level. This performance criterion was chosen from practical reasoning. In Switzerland, a full season of ice hockey contains about 50 games, so the

requirement to have played two entire seasons should distinguish one-season wonders or gap fillers from players able to assert themselves as ice hockey professionals. There are players that did not spent the beginning of their adult ice hockey career (age 20 to 24) in Switzerland. The Top two Swiss ice hockey leagues are on a similar level as the leagues in the USA and Canada (NHL, AHL, ECHL), Sweden (SHL, HockeyAllsvenskan) or Finland (Liiga, Mestis). Therefore, we considered games in the foreign Top two (or three) leagues equivalent to playing games in the Top two leagues in Switzerland.

Data analysis

Talent development deals with analyses in the context of developing human individuals and so is considered a multidimensional phenomenon.[32] Thus, this study is oriented on the dynamic interactionist approach of developmental science.[41,42] However, from a methodological standpoint, it is not possible to picture such complex systems. Rather only different states of the dynamic system can be associated with each other by using snapshot linking. From a developmental perspective, the concepts of general linear models based on a variable-oriented method and a “one-model-fits-all” approach are highly questionable, and it is assumed instead that non-linear interactions appear between single characteristics within human individuals.[41] Therefore, for talent development research, it seems more appropriate to employ a person-oriented approach focusing on the individual and searching for non-linear patterns of a set of variables within individuals. Two main aspects of person-oriented studies can be highlighted: 1) it is possible to account for compensation effects among the included set of variables (e.g., hours in free play could compensate for lower amounts of in-club practice) and 2) it is possible that successful players with different pathways in their career can be identified. The person-oriented Linking of Clusters after removal of a Residue (LICUR) method was used to analyze the data. It follows a three-step procedure: 1) Residual analysis to determine and remove extreme cases that would bias the following cluster solution. 2) Cluster analysis to assign subjects to clusters of similar patterns. 3) Transition analysis computing frequencies of

transition from clusters to a predetermined criterion.[42] The statistical procedures were carried out using the statistical package ROPstat.[43]

First, we have analyzed intercorrelations among the variables that operationalize early sport participation.[44] It is suggested that if intercorrelations between two variables exceed $r = .90$, using only one of the variables is sufficient due to redundancy.[45] Overall, no correlation exceeded $r = .90$. However, there are significant intercorrelations between the volume of organized in-club ice hockey practice and the age at first ice hockey club participation ($r = -.60$, $p < .01$) and volume of free play within hockey and age at first ice hockey club participation ($r = -.32$, $p < .01$).

The residual analysis (Residue module in ROPstat[43]) compares individuals based on their patterns in the four variables. A twin-search method (nearest-neighbor procedure) was used to identify pairs of individuals that show similar patterns using the squared Euclidean distance. In line with other person-oriented studies, cases that exceed a threshold of $T = 0.8$ are considered extreme cases.[32,42] Thus, individuals that show a larger distance to their nearest neighbor are removed as residuals. This residual analysis led to the exclusion of three cases. This is a plausible percentage of residues to exclude (about 3% of the whole sample).[42] The residuals were analyzed separately, but they did not show any promising patterns.

For the following cluster analysis (Cluster module in ROPstat[43]), the four variables of early sport participation were used. As recommended for person-oriented studies, a hierarchical analysis with the squared Euclidean distance and the Ward procedure was applied.[42] To determine the most appropriate cluster solution, five statistical criteria[42,43,44,46] as well as content-based criteria were considered: 1) The two-third criterion of explained error sum of squares (*EESS*)[42] as indication for data cohesion . 2) The Mojena stopping rule that proposes a threshold between 1.80 and 2.75[45,46], which is based on changes in standardized fusion coefficients to assess the heterogeneity of cluster solutions. 3) The silhouette coefficient (*SC*) evaluates the distance of each individual to its own as well as the closest center of another cluster. Acceptable values are $SC > 0.5$.[44] 4) The average homogeneity coefficient (HC_{mean}) is a measure for data cohesion.[44] Thus, it describes the cluster stability among all clusters and is

sufficient if HC_{mean} < 1.0. 5) The Cluster point-biserial correlation (*PB*) is a separation index that evaluates the association of distances within and between clusters. In a stable cluster solution, distances within clusters are smaller than between clusters. Thus, acceptable value ranges are *PB* > 0.5; *PB* < -0.5.[44] Subsequently, a non-hierarchical cluster analysis (*k*-means method in ROPstat[43]) was performed to optimize the respective cluster homogeneities.

Finally, we analyzed transitions from each cluster of early sport participation to the performance criterion in adulthood using *Fisher's exact test* with a hypergeometric distribution for significant deviations from an equal distribution. In so doing, we tested whether clusters (*k* = 4) showed significantly higher probability compared to equal distribution to be assigned to a specific characteristic of the performance criterion (*k* = 2). The number of transitions was represented as a multiple of the expected value and expressed using odds ratios: *OR* = 1.0 is the expected value; *OR* < 1.0 means fewer and *OR* > 1.0 means more transitions than predicted by chance.

Results

The results of the LICUR analysis showed that several cluster solutions could have been extracted (cf. Table 1). The three-cluster solution did not meet most of the outlined criteria to determine the number of clusters. The *EESS* only accounted for 47.68%, which is far below the suggested two-third criterion[42]. In addition, also the HC_{mean} was only within acceptable range (HC_{mean} = 1.06). Only silhouette coefficient (*SC* = 0.68) and cluster point-biserial correlation (*PB* = 0.52) showed acceptable to good values. Moreover, the three-cluster solution is the only one, which has crossed the Mojena stopping threshold (Mojena = 2.90).[46] However, the three-cluster solution overall does not show an accurate and stable differentiation of the analyzed data. The five-cluster solution showed overall acceptable to good values. It met the suggested two-third criterion for the explained error sum of squares (*EESS* = 67.98%) and demonstrated a high average homogeneity within clusters (HC_{mean} = 0.67). It showed acceptable values for silhouette coefficient (*SC* = 0.67) and point-biserial correlation (*PB* = 0.44). However, it did not exceed the Mojena stopping threshold of 2.75 (Mojena = 1.55)

nor is it in the suggested range of 1.80-2.75.[45,46] The four-cluster solution did not meet the desired two-third criterion (*EESS* = 60.6%) and performed acceptable for the average homogeneity (HC_{mean} = 0.82). Moreover, the four-cluster solution showed good values for point-biserial correlation (*PB* = 0.54) and silhouette coefficient (*SC* = 0.72). Lastly, it also did not exceed the suggested Mojena stopping threshold of 2.75 (Mojena = 2.13) and is in the recommended range.[45]. Overall, the statistical characteristics only show a slightly more stable and accurate differentiation for the four-cluster solution compared to the five-cluster solution. Thus, in person-oriented studies, it is additionally suggested to consider content-based criteria to decide, which cluster solution might be most appropriate. Therefore, we have checked which clusters merge in the fusion process from the five- to the four-cluster solutions and whether these merging clusters already show similarities. We were able to find that the two clusters only differed in age of initial ice hockey club participation (Cluster 4 [C4]: age = 5.24, *z* = -0.20; Cluster 5 [C5]: age = 7.92, *z* = 1.32). Comparing the amount of in-club practice in primary sport (C4 = 1,099 hours, *z* = -0.49; C5 = 850h, *z* = -0.80), the amount of free play in primary sport (C4 = 1,303 hours, *z* = -0.39; C5 = 1,070 hours, *z* = -0.56) and the amount of other sports (C4 = 341 hours, *z* = -0.38; C5 = 320 hours, *z* = -0.40) the two clusters showed comparable values. Therefore, regarding simplicity and interpretability, the four-cluster solution seems to be appropriate and reasonable.

Table 1. Results for the statistical criteria to determine the most appropriate cluster solution for the three-, four- and five-cluster solution.

	3-cluster solution	4-cluster solution	5-cluster solution
EESS (in %)	47.68	60.60	67.98
Mojena stopping rule	2.90	2.13	1.55
SC	0.68	0.72	0.67
HC_{mean}	1.06	0.82	0.67
PB	0.52	0.54	0.44

Note: *EESS* = Explained error sum of squares; *SC* = Silhouette coefficient; HC_{mean} = Average homogeneity coefficient; *PB* = Cluster point-biserial correlation.

Table 2 shows the distribution of early sport participation up to 12 years of age throughout the entire study sample and in each specific cluster. To summarize, the total average amount of early sport participation up to 12 years of age was 3,977 hours. On average, the players entered ice hockey clubs at 5.6 years of age (*SD* = 1.7). The longest duration of players' learning activities was in the context of free play (1,827 hours, 45.9%). The average duration for in-club practice was 1,494, which accounts for 37.6% of the total. Poly-sportive activities accounted for the shortest duration of all learning activities (656 hours, 16.5%).

Table 2. Descriptive statistics of early sport participation factors for four clusters of Swiss ice hockey players.

Clusters	In-club practice of primary sport (hours)		Free play of primary sport (hours)		Other sports (hours)		Club entry (years of age)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Ice hockey enthusiasts (*n* = 15)	1,626	407	4,219	1,248	298	448	4.9	0.9
Specialized club players (*n* = 15)	2,742	714	1,243	797	250	430	4.0	1.1
Poly-sportive players (*n* = 18)	1,771	532	1,937	786	2,130	514	4.7	1.3
Late-starting hockey abstainers (*n* = 47)	947	392	1,208	632	336	386	6.7	1.6
Total (*N* = 95)	1,494	802	1,827	1,340	656	832	5.6	1.7

Ice hockey enthusiasts have by far the most hours of hockey free play (4,219 hours). Nevertheless, they show a slightly above-average share of sport-specific in-club practice (1,626 hours), while their age at first club participation lies within the average range (4.9 years of age) and their engagement in other sport activities is below average (298 hours). From these statistics, it is obvious that players in this cluster spent their leisure time playing hockey in addition to their large amount of in-club practice.

Specialized club players are those who devoted the majority of their sporting activities to targeted, sport-specific, in-club practice (2,742 hours). In addition, this cluster shows below-average age at first club participation (4.0 years of age), a below-average level of participation in hockey free play (1,243 hours), and the least amount of poly-sportive activities (250 hours).

Compared with the other clusters, *poly-sportive players* exhibit a very high degree of other sporting activities (2,130 hours). In addition, they show a slightly above-average level of in-club practice (1,771 hours), a rather low age at first club participation (4.7 years of age), and an average amount of hockey free play (1,937 hours).

Finally, *late-starting hockey abstainers* have below-average values across all four factors. They are characterized by a high age at first club participation (6.7 years of age) and demonstrate low amounts of in-club practice (947 hours), hockey free play (1,208 hours), and other sporting activities (336 hours).

In Figure 2, we have displayed transitions from the early sport participation clusters to the performance criterion of adult performance level. In so doing, we have plotted *z*-scores of the four factors of early sport participation for the four cluster solutions. The x-axis represents the four factors. The results of the *Fisher's exact test* analyzing significant deviations from an equal distribution of the four clusters to the performance criterion indicate two significant deviations. Compared to the other clusters in the sample, *ice hockey enthusiasts* showed a significantly higher probability of playing ice hockey at a professional performance level in adulthood (OR = 3.54 [1.04; 12.06], p = .0487), and a significantly lower probability of playing ice hockey at a non-professional performance level in adulthood (OR = 0.28 [0.08; 0.96], p = .0487). All the other clusters did not show significant results in testing transition to adulthood performance level and, therefore, did not show different probabilities regarding the likelihood of playing at a professional or non-professional performance level in adulthood.

--- Insert Figure 2 about here ---

Discussion

This study conducted the first quantitative investigation into how early sport participation in ice hockey is associated to players' performance level in adulthood. The results show that the sub-group of former junior national team players who engaged in high amounts of free hockey play and above-average in-club practice up to the age of 12 (*ice hockey enthusiasts*) were most likely to achieve expertise. Therefore, it seems that currently successful ice hockey players are distinguished by specializing in ice hockey but engaging in a diverse range of learning activities in different settings within the domain (i.e., practice and play).

A comparison of the different patterns of early sport participation in ice hockey players shows that *ice hockey enthusiasts* and *poly-sportive players* had a similar amount of in-club practice and a similar age at entering the club. However, they differed by approximately 2,000 hours for both free hockey play duration and other sports duration. We assume that the extensive practice of other sports by *poly-sportive players* lowered their likelihood of developing expertise compared with *ice hockey enthusiasts*, who chose to engage in free play within ice hockey. Furthermore, *specialized club players* are only successful by chance, whereas *ice hockey enthusiasts* with high amounts of free play have a significantly higher probability of developing expertise in ice hockey. Therefore, it might be reasonable to suppose that in addition to basic enjoyment of a sport, a high amount of free play in the chosen domain during childhood increases the likelihood of achieving expertise in adulthood. Furthermore, based on this study's results, it can again be hypothesized that, in game sports, neither of the two poles of the early specialization approach and the early sampling approach seems able to explain the development of sporting expertise in adults. Rather, an approach that lies between the two poles seems to be most suitable for explaining the development to subsequent expertise in ice hockey. Comparing the results with previously postulated approaches lying between the two opposite poles (e.g., early engagement hypothesis, specialized sampling model), it might be reasonable to assert that *ice hockey enthusiasts* are closer to the early specialization approach (compared to the early sampling approach) as they are already highly specialized within their sport domain prior to 12 years of age. Therefore, their developmental

pathway of early sport participation might be best described by the specialized sampling model (see Table 3).

Regarding the posited similarities in early sport participation across sport domains with comparable characteristics and similar constellations of sport-specific constraints (age of peak performance, performance density and selection pressure, physiological and psychological requirements), we find similarities between our results for Swiss ice hockey and previous findings for Swiss football.[12,32] All three studies can make reasonable assumptions that *enthusiasts*, whose constellations combine high involvement within the domain, especially regarding free play activities, and low involvement in other sport domains, are most likely in their respective age group to develop expertise. It is, therefore, plausible that sport-specific constraints determine the constellations of early sport participation up to 12 years of age. Further, we may derive that similar types of sport domains create similar constellations of sport participation in childhood.[30]

Hence, this comparison supports the assumption that currently successful Swiss ice hockey players have followed the specialized sampling model, similar to participants in the Swiss football studies.[12,32] Therefore, for ice hockey, the specialized sampling model seems to be the most promising pathway of early sport participation for developing expertise, considering the existing sport-specific constraints.

Having discussed the study's results with respect to recent studies in a comparable sport domain, we wish to anchor the specialized sampling model among existing theories. In Table 3 we supplement the comparison of different approaches to early sport participation[29] by showing the percentage distribution of accumulated hours of learning activities during sport participation up to 12 years of age. The table includes the early specialization approach (using figures derived from theoretical considerations); the specialized sampling model (using figures derived from the empirical data in this research and Sieghartsleitner et al.[12]); the early engagement hypothesis (using figures derived from the empirical data in Ford et al.[25]); and the early sampling approach (using figures derived from theoretical considerations).

Table 3. Percentage shares of forms of early sport participation (from age 0 to 12) using different approaches (table adapted from Ford and Williams[28], p. 118).

	Early specialization approach[1]	***Specialized sampling model[2]***	***Early engagement hypothesis[3]***	***Early sampling approach[1]***
Play *(%)*	0–10	45–55	40–50	15–25
Practice *(%)*	65–75	25–35	15–30	0–15
Competition *(%)*	10–20	5–10	0–5	0–5
Other sports *(%)*	0–5	5–15	15–25	55–65

Note: [1] Figures derived from theoretical considerations; [2] Figures derived from empirical data in this research and Sieghartsleitner et al.[12]; [3] Figures derived from empirical data in Ford et al.[25] Assignment of figures to terms used in Ford and Williams[28], p. 118: None = 0%, Low ≤ 15%, Medium = 16–34%, High = 35–54%, Very High ≥ 55%.

Table 3 shows that the opposite poles of early sport participation are highly different regarding the four characteristics described. The early specialization approach contains hardly any participation in other sport domains, whereas the early sampling approach prescribes devoting the largest amount of time to other sport domains. For the two early sport participation approaches between the poles, there are only small differences in the percentage distributions between the specialized sampling model and the early engagement hypothesis. Table 3 suggests that the specialized sampling model is slightly closer to the early specialization approach than the early engagement hypothesis: both have a higher degree of domain specificity than the early engagement hypothesis, as shown by the lower number of hours devoted to other sports.

However, additional relevant differences are explained by the evolution of the early engagement hypothesis and the specialized sampling model. The early engagement hypothesis is based on empirical findings only. By contrast, the specialized sampling model considers early sport participation as a two-dimensional continuum that combines the polar opposites of specialization (high domain specificity and practice) and sampling (low domain specificity and play) into a superior model, at least for game sports in Switzerland. The early

specialization approach prescribes highly structured practice, with high amounts of repetition as the underlying learning mechanism.[47] Yet such intense and focused practice may lead to a lack of intrinsic motivation.[48] The early sampling approach assumes a distinct learning mechanism, namely that sampling experiences in different sports will lead to the development of general fitness and skills that can be transferred.[19] Moreover, the playful learning activities favored by this approach are associated with an improvement in general fitness and higher intrinsic motivation, which correlates with a lower dropout rate. The specialized sampling model combines the positive aspects of the learning mechanisms of the two poles and buffers against their respective weaknesses. In ice hockey, young talents following the specialized sampling model will develop technical skills in highly structured practice. This monotone learning mechanism is compensated by enjoying playing street hockey, where players can apply their newly learned skills in an informal and playful setting. Furthermore, other positive effects accompany playful learning activities, such as active biological and psychological recovery[49], which compensates for the heavy demands of highly structured practice.

Limitations and future research

Five limitations of the current research should be noted. First, retrospective data collection always raises questions regarding data reliability. Although collection of the volume of training is a reliable process[35], people struggle with uncertainty and forgetting.[39] The current study discussed problems of reliability and how to diminish them. To avoid problems with long-term recall, further studies of ice hockey could investigate early sport participation by using prospective research designs.

Second, the operationalization of deliberate practice was based on an estimate rather than accurate numbers. The amount of systematic, highly structured practice was deduced by the hours of in-club practice. This operationalization was criticized as potentially too short-sighted and, therefore, not sufficiently adequate to determine the amount of systematic and purposeful practice.[50] Future studies should follow the guidance of Tedesqui et al.[50] by further differentiating in-club practice and systematic, structured, purposeful practice.

The third limitation concerns the proposal that similarly pronounced sport-specific constraints are shared by different sports.[30] This study assumes the existence and relevance of sport-specific constraints that are related to successful approaches of early sport participation. However, future studies should vary these constraints by investigating other sports to verify whether the same or different successful approaches can be identified. Moreover, sport-specific constraints (i.e., age of peak performance, selection pressure, physiological/psychological requirements) may differ between countries. It would be valuable to investigate how countries distinguish sport-specific constraints.

Fourth, only former U16 junior national team players have been included. Swiss ice hockey is selecting quite broad (M = 44.36, SD = 18.77) for U16 national team. Thus, it is probable that most active professional players have been considered within our population. However, it is possible that there are cases of players that went through the early sampling pathway and have not been selected for the U16 national team, who still achieved professional performance level in ice hockey. We have therefore checked, if there are players that have not been selected for the U16 junior national team and still achieved professional performance level. In total, there are N = 358 players born between 1984 and 1994 that have played 100 or more games until the age of 24. In our sample, n = 261 (73%) have been considered and n = 97 (27%) were not included.

Lastly, the response rate of 20.1% accounts for a minority of the entire population of former junior national ice hockey player born between 1984 and 1994. Although we have found no differences between the study sample and the entire population regarding adult performance level, the representativeness of the study sample should be interpreted with caution.

Conclusion

Previous research has shown that neither of the two polar approaches to early sport participation (i.e., early specialization vs. early sampling) is capable of developing sporting expertise in popular game sports.[12,27] The current study reinforces these findings and also

provides evidence that a combination of early specialization and early sampling seems to be more appropriate for developing sporting expertise. In Swiss ice hockey, the specialized sampling model seems to be the most promising approach as it comprises learning activities with high domain specificity that are sampled through various experiences with different degrees of performance orientation within this domain.[12] Furthermore, this study's results indicate that it is possible to find similar successful constellations of early sport participation in game sports in Switzerland with comparable sport-specific constraints (cf. Swiss football in Sieghartsleitner et al.[12]). However, investigations of other sports are needed to advance our understanding of these constraints and their impact on programs to develop sporting expertise.

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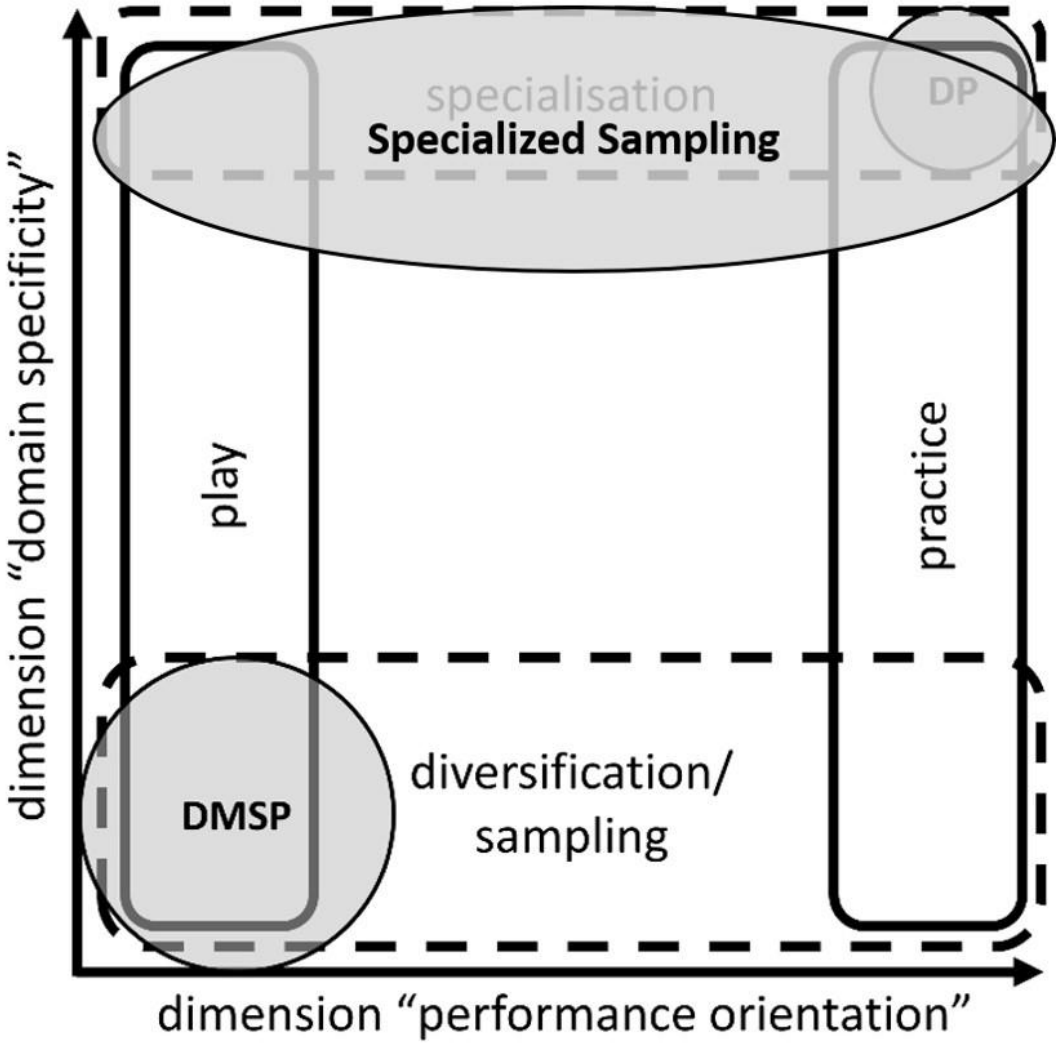

Figure 1. Modified specialized sampling model within the two-dimensional construct of domain specificity and performance orientation. The specialized sampling model is classified through comparison with the early specialization approach (deliberate practice framework [DP], Ericsson et al., 1993) and the early sampling approach (Developmental Model of Sport Participation [DMSP], Côté, 1999) (modified from Sieghartsleitner et al., 2018).

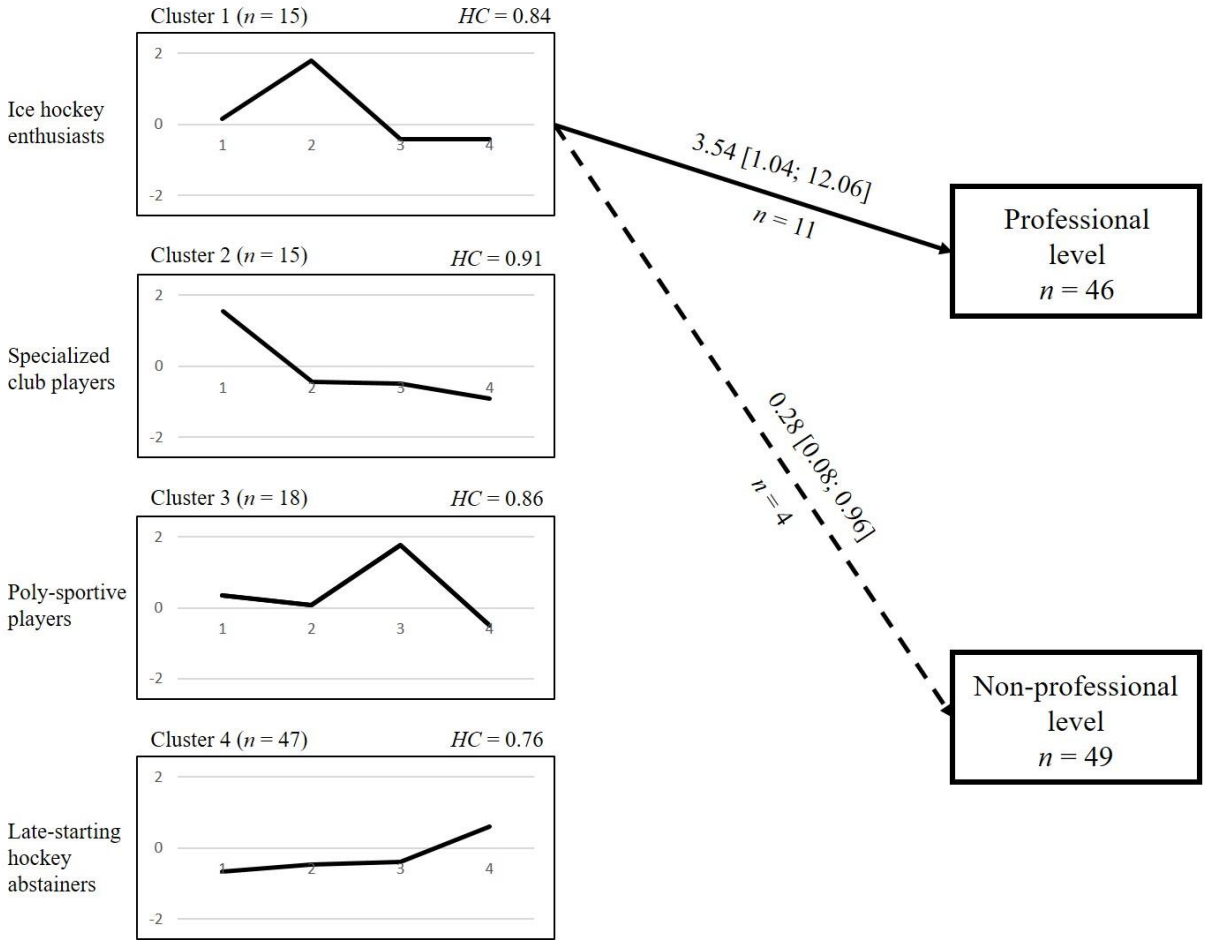

Figure 2. Profiles of *z*-scores of the four clusters of early sport participation and the transitions to adult ice hockey performance levels, with odd ratios, 95% *CI* and *n* = significant transitions. Factors in cluster plots: 1 = volume of organized in-club ice hockey practice; 2 = volume of free play within hockey; 3 = volume of other sport activities; 4 = age at first ice hockey club participation. Performance criterion: Professional level ≥ 100 games played in the 1st and/or 2nd highest Swiss or foreign league; Non-professional level < 100 games played in either league. *HC* = heterogeneity coefficient.