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Research article

Motor Learning as Young Gymnast's Talent Indicator

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Abstract

Talent identification plans are designed to select young athletes with the ability to achieve future success in sports. The aim of the study was to verify the predictive value of coordination and precision in skill acquisition during motor learning, as indicators of talent. One hundred gymnasts, both cadets (aged 11.5 ± 0.5 yr.) and juniors (aged 13.3 ± 0.5 years), competing at the national level, were enrolled in the study. The assessment of motor coordination involved three tests of the validated Hirtz's battery (1985), and motor skill learning involved four technical tests, specific of rhythmic gymnastics. All the tests were correlated with ranking and performance scores reached by each gymnast in the 2011, 2012, and 2013 National Championships. Coordination tests were significantly correlated to 2013 Championships scores ($p < 0.01$) and ranking ($p < 0.05$) of elite cadet athletes. Precision, in skill acquisition test results, was positively and significantly associated with scores in 2013 (adj. $R^2 = 0.26$, $p < 0.01$). Gymnasts with the best results in coordination and motor learning tests went on to achieve better competition results in three- year time.

Key words: Training, precision, coordination, talent selection, gymnastics, motor skills.

Introduction

One of the main tasks of National Sports Federations is to identify, select, and prepare athletes for international competitions such as the Olympics Games, World and European Championships, and World Cups. Sport managers and coaches try to pick out future champions using psychological, physical, technical, and anthropometric criteria (Harris and Atkinson, 2009). However, if the selection process is attempted too early, it could lead to numerous mistakes, and it is possible for a promising champion to fail the enrollment at a relatively early age. A correct selection is fundamental because, after some years of deliberate practice, the gap between selected and unselected athletes becomes insurmountable, and it is impossible to dredge talented athletes who were previously excluded by mistake (Bullock et al., 2009).

When considering anthropometric measurements and motor skills as good indicators to select athletes (di Cagno et al., 2008), it is necessary to keep in mind that during puberty, which is an unstable period, the evaluation of young athletes is complicated by individual differences in the timing of changes in body size and functional capacities (Philippaerts, 2006; Unnithan et al., 2013). It is possible that pre-adolescents, who possess the characteristics required by a sport, will not retain these qualities throughout maturation until adulthood and that these innate capacities may not turn into exceptional adult sport performance (Ackland and Bloomfield, 1996; Beunen et al., 1981). On the contrary, many of the qualities that distinguish the performance of an excellent adult athlete do not necessarily appear evident during childhood or puberty (Philippaerts, 2006).

To avoid prematurely eliminating talented young athletes who are currently not "performing", it is essential to distinguish between variables that influence performance and those that influence development (Abbot and Collins, 2002). Biological maturation affects morphology and fitness more so than motor coordination skills (Vaeyens et al., 2006). Recent findings showed moderate to high long-term stability in coordinative skills and sport-specific skills from childhood to adolescence (Ahnert et al., 2009; Vaeyens et al., 2006). A motor coordination test might be valuable in the early talent identification of gymnasts, as its discriminative and predictive qualities might be sufficiently powerful for selection (Vandorpe et al., 2012). Motor coordination has a high stability as talent indicator for child to adolescent athlete selection (Ahnert et al, 2009). Motor learning capacity may be considered a prerequisite for the learning of specific skills in gymnastics and is especially strong in the pre-adolescent period, identified as a "sensitive phase" in which the talent selection is carried out (Hirtz and Starosta, 2002; Starosta and Hirtz, 1989), recognizing and exploiting the capacity to develop. It is essential to select based on an athlete's ability to develop, rather than simply on a good performance level at the time of testing (Abbott and Collins, 2002; 2004). Motor learning capacity may be a determinant of the potential that an individual has to develop within a sport.

The Italian Gymnastics Federation has used two traditional strategies in current talent selection programs, consisting of the competition results evaluation and specific rhythmic gymnastics tests. Both of these are strongly affected by the gymnast's personal experience in their clubs. The main purpose of the study was to verify whether the predictive value of coordination and precision in skill acquisition during motor learning, could be valid and long-term indicators in selecting talent among young rhythmic gymnasts, and related to performance in competition three years later. The precision in the tests requires body segments to be held correctly during the movements, as well as good balance, good amplitude of

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Table 1. Technical element descriptions at each level.

	Leap	Pivot	Risk with throw 1	Risk with throw 2
Cadets	Entrelacé	720° Front split "with help"	Rope: One rotation around the horizontal axis of the body with passing to the floor and catch without hands	Hoop: One rotation around the horizontal axis of the body with passing to the floor and re-throw of the apparatus
Junior	Entrelacé with split leap and with ring	360° (or more) Splits "without help"	Ball: One rotation around the horizontal axis of the body with passing to the floor and catch out of the visual field and without hands	Clubs: One rotation around the vertical axis of the body without passing to the floor and re-throw of the apparatus and during the flight one rotation around the horizontal axis of the body

movement shapes, and precise direction and plane of execution. We hypothesized that motor coordination and skill acquisition tests could be valuable in the early identification of gymnasts, both in cadet and in junior gymnastics categories, and has a predictive value for future performances in competition, independently from the gymnast's level of performance (elite or sub-elite).

Methods

Participants

One hundred athletes of rhythmic gymnastics were enrolled in the study including 41 elite competing at the national level, divided into two age categories: 20 cadets (age: 11.5 ± 0.5; training: 25.0 ± 10.2 hours per week^{-1}) and 21 juniors (age: 13.3 ± 0.5; training: 30.7 ± 14.1 hours per week^{-1}) and 59 sub-elite competing at the regional level (age: 10.5 ± 0.5; training: 20.5 ± 3.3 hours per week^{-1}). The Italian Gymnastics Federation selected the athletes, elite and sub-elite, to participate in different national summer trainings, depending on technical levels. The participants were selected for the 2010 national summer training. The following exclusion criteria were applied: less than two years of gymnastic training and no health problems or injuries. The study was designed according to the Declaration of Helsinki and was approved by the local Ethics Committee. Parents of underage athletes (less than 18 years old) gave their written consent for the study.

Study design

Three non-sport specific motor coordination tests within the battery validated by Hirtz (1985) and four technical elements specific of rhythmic gymnastics, had been correlated with ranking and performance scores reached by each gymnast in the 2011, 2012, and 2013 National Championships, to verify if coordination and precision in skill acquisition during motor learning, could be valid and long-term indicators in selecting talent among young rhythmic gymnasts.

Technical elements and assessments

The four specific technical elements were a leap, a specific tour named "pivot", and two "risk with throw of apparatus" elements. Table 1 provides descriptions of the four technical elements and Figure 1 provides schematics of the four elements at each level. The selected elements required high coordinative skills and were unknown to the gymnasts. The chosen jump required lower limb kinesthetic discrimination and orientation ability (Pehoiu, 2010). The chosen pivot required a high level of dynamic balance and limb response orientation ability. The two "risk with throw" elements required upper limb kinesthetic discrimination abilities and dynamic balance.

The three motor coordination tests assessed kinesthetic discrimination, response orientation abilities, and dynamic balance. The "low jump test" assessed lower limb kinesthetic discrimination ability. The "orientation shuttle run test" assessed lower limb response orientation ability. The "backwards ball throw test" assessed upper limb kinesthetic discrimination ability. Table 2 provides descriptions of the three motor coordination tests. This battery has high test/retest reliability (Intra-class correlation coefficient (ICC)) (r = 0.97, p = 0.000) (Zetou, et al., 2012).

The evaluation was based on precision in the execution of the tests, following the penalties of the International Code of Points in Rhythmic Gymnastics (ICP) (International Rhythmic Gymnastics Committee, 2013). The precision in the tests requires body segments to be held correctly during movements as well as good balance, good amplitude of movement shapes, and precise direction and plane of execution.

Procedures

In the 2010 national summer training the gymnasts underwent a pre-test based on three motor coordination tests and four specific technical element tests after a 30-minute warm up. Each element was first explained verbally by the coaches and then demonstrated by an athlete. An evaluation scale from zero to five points, with penalties of 0.10 for small faults, 0.20 for medium faults and 0.30 to 0.50 for major faults, based on ICP criteria, was chosen for this study. Each element was repeated three times and the best results were considered.

In the training intervention the gymnasts were allowed ten days to learn the technical elements. Training sessions were twice per day (20 sessions), half an hour for each session. Three sets of ten trials for each element, with 30-sec. rest periods between trials and two-min. rest periods between sets were performed in each session. Each set was followed by coach feedback.

The evaluation of the specific technical elements was carried out in the middle of the experimental period (intermediate-test scores on the fifth day) and at the end (post-test scores on the 10th day). The ranking and the scores of the 2011, 2012, and 2013 National Championships in which the gymnasts had participated were collected.

Statistical analysis

The sample Kolmogorov-Smirnov test for normality was applied to check that sample data were normally distributed. Pearson product moment correlation was conducted to assess the relationship between the variables measured at the initial testing and the 2011, 2012, and 2013 competition outcomes.

The amount of variance in ranking and scores in the three National Championships was calculated using linear regression analysis for each group separately.

The α level was set at $p \leq 0.05$, and the analyses were conducted using SPSS statistical package software (SPSS, v.20.0 Inc., Chicago, IL, USA).

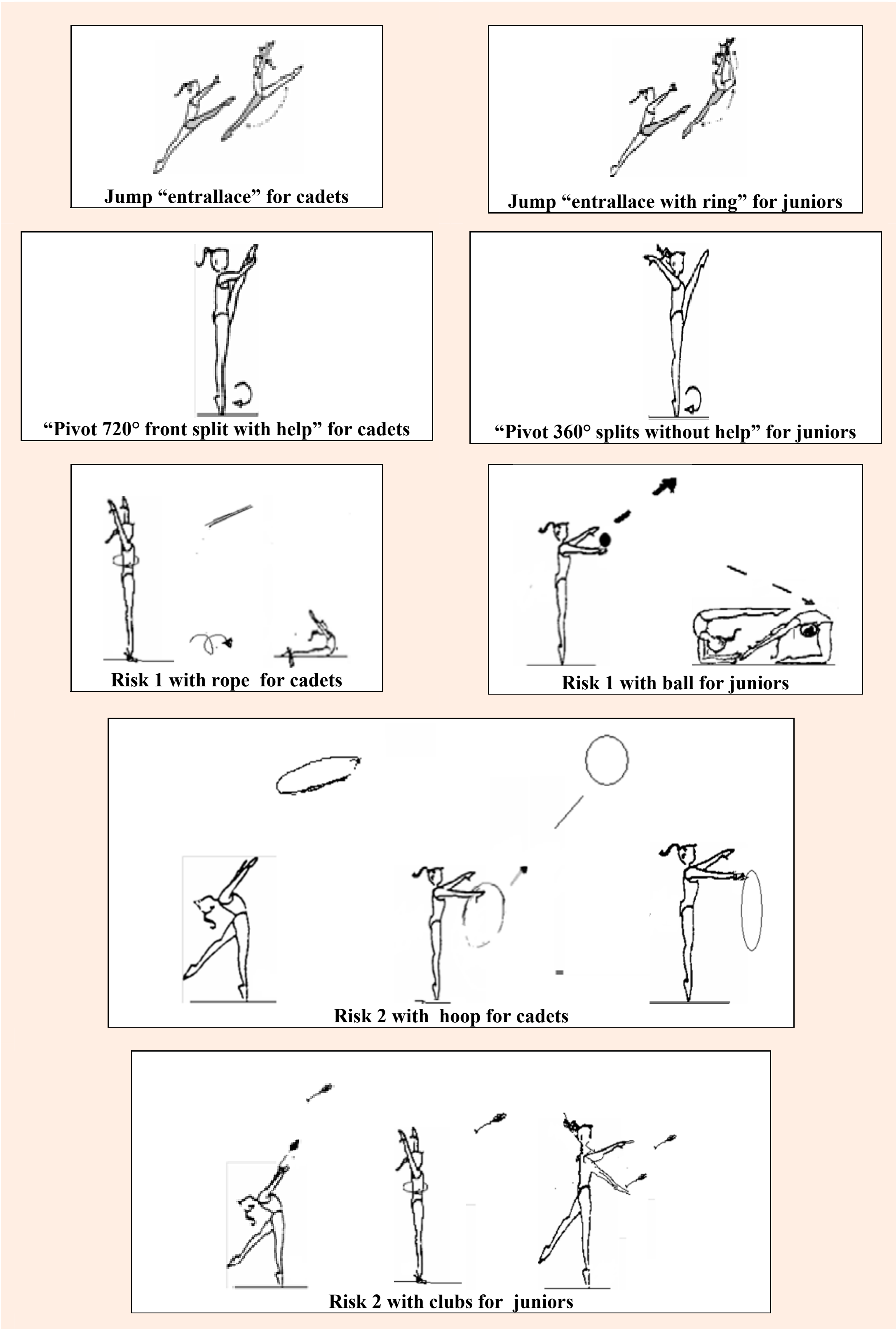

Figure 1. **Schematics for the technical elements.**

Table 3. Pearson's correlations between Hirtz's battery tests and the score and ranking in the 2011, 2012 and 2013 National Championships.

	Junior						Cadet elite						Cadet sub elite					
	Score			Ranking			Score			Ranking			Score			Ranking		
	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013
Low jump (cm)	.29	.06	-.35	.18	-.08	.36	-.23	-.11	-.54**	.46*	.26	.65**	-.44**	-.35*	-.28*	.30*	.26*	.38**
OSRT (sec)	-.28	.47*	-.55**	.04	.19	.42	-.06	-.21	-.27	.04	.03	.13	-.20	-.17	-.27	.28*	.27*	.27*
BBTT (score)	.41	-.13	.40	-.15	-.37	-.25	.28	.23	.59**	-.13	-.12	-.50*	.02	-.09	.03**	.09	.09	-.03

OSRT: Orientation shuttle run test . BBTT: Backwards ball throw test ; * Significant at 0.05 level, ** Significant at 0.01 level

Table 2. Hirtz's battery test descriptions.

Test	Description
Low jump test	To assess lower limb kinesthetic discrimination ability. Participants jumped with the legs together from a plinth to a ground marking at a set distance (1 m). They were instructed to land with their heels on the marking. The test was performed twice and the distance of each heel from the marking was measured in centimeters for each trial. Distance values were collapsed across heels and trials to obtain one mean value.
Orientation shuttle run test	To assess lower limb response orientation ability. The participant was instructed to run three times, as quickly as possible, from a start marker toward one of five numbered goal markers located behind her. The goal markers were 3m apart from her and 1.5m apart from another on a hypothetical circumference arc. The sequence of goal markings to be reached was not known previously. The next marking number was announced when the participant returned to the start ball and touched it for the next run to begin without pausing. After demonstration by an experimenter, participants performed the test that was scored in seconds.
Backwards ball throw test	To assess upper limb kinesthetic discrimination ability. Participants performed a one-hand overhead throw backwards with a tennis ball. They were instructed to center a ground target located 250 cm behind the performer. The target had a 20 cm diameter. After a training throw, participants performed five consecutive trials. Five points were assigned for each centered target. Scores of 4, 3, 2, 1 and 0 were assigned with increasing distance of the contact point of the ball from the target and the mean score was computed.

Results

The *P* value of the sample Kolmogorov-Smirnov test results ($p = 0.05$ in leap; $p = 0.060$ in pivot; $p = 0.120$ in 'risk with throw 1'; $p = 0.971$ in 'risk with throw 2') confirmed that the sample data was normally distributed. Correlation coefficients between Hirtz's battery tests and score and ranking in the 2011, 2012, and 2013 National Championships are shown in Table 3.

Significant correlation between motor learning precision and both ranking and scores in 2011, 2012, and 2013 National Championships are shown in Table 4.

By linear regression analyses we examined the predictive value of those variables that significantly correlated with the results in competition. Considering junior athlete, the "Orientation shuttle run test" score predicted the results in competition three years later and explained a significant proportion of variance in competition scores ($R^2 = 0.30$; adj $R^2 = 0.26$; $p < 0.05$). Considering cadet elite, low jump test and backwards ball throw test explained the variance in 2013 competition scores ($R^2 = 0.28$; adj $R^2 = 0.24$; $p < 0.05$ and $R^2 = 0.35$; adj $R^2 = 0.31$; $p < 0.01$, respectively). For cadet sub elite low jump test explained the variance in 2013 competition scores ($R^2 = 0.08$; adj $R^2 = 0.06$; $p < 0.05$).

The linear regression analyses showed that precision in motor skills learning explained the variance in the scores of elite (2011: adj $R^2 = 0.05$, $p < 0.05$; 2012: adj $R^2 = 0.119$ $p < 0.01$) and sub elite cadet gymnasts (2011: adj $R^2 = 0.225$, $p < 0.01$; 2012: adj $R^2 = 0.176$ $p < 0.01$).

Precision explained the variance of elite cadet scores in 2013 (adj $R^2 = 0.489$, $p < 0.01$) (Figure 2).

Table 4. Pearson's correlations (r) between motor learning precision with the scores and ranks gained in the 2011, 2012, 2013 National Championships.

National Championship	Pearson's Correlation	
	Scores	Rank
2011	.238 *	-.278 **
2012	.359 **	-.217 *
2013	.522 **	-.444 **

* Significant at 0.05 level ** Significant at 0.01 level

Discussion

The aim of the present longitudinal study was to verify the predictive value of coordination and precision in skill acquisition during motor learning, as indicators of talent, in order to foresee future competition outcomes for young gymnasts. The main result was that coordination and precision in the motor learning process could be long-term predictors of a gymnast's potential for achieving future success in competition and consequently a more sensitive measurement of ability in the sport at an early age (Vaeyens et al., 2006).

Precision in skill acquisition explained 50% of the variance three years later in competition scores for elite cadets, whereas only 20% in competition scores for sub elite cadets and juniors, affirming that precision in the motor learning process is highly predictive for young promising gymnasts. Cadet athletes who are at a golden age for motor learning (Starosta and Hirtz, 2002), characterized by sensitive phases for coordinative skills (Hirtz and Starosta, 2002; Starosta and Hirtz, 1989), showed better motor learning ability for new technical elements than juniors. Juniors who demonstrated current ability rather than the potential to excel (Philippaerts et al., 2008) were more constant performers but were not precise with new movements (Biro et al., 2003). A clear stagnation and impairment could be expected during pubertal growth (Starosta and Hirtz, 1989). Given that this trend is more evident in elite gymnasts, it follows that motor learning may be a better indicator of talent for elite athletes than sub-elite.

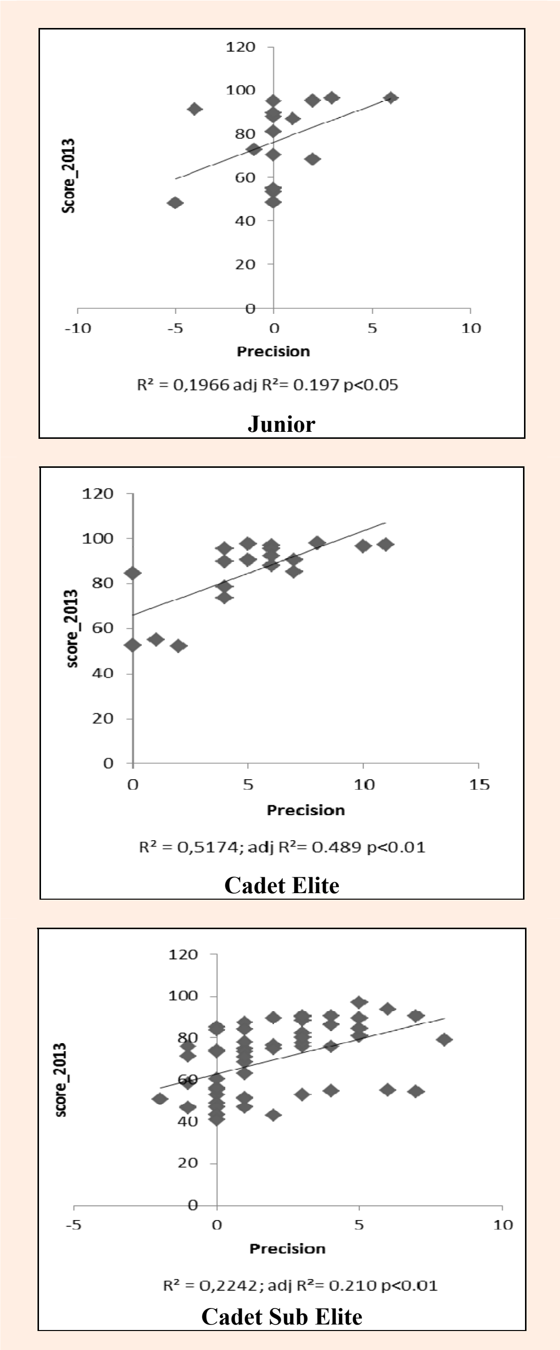

Figure 2. Linear regression analyses using motor skill learning precision as predictor of scores and ranking of 2013 Italian National Championship.

A novelty of this study was the proposal of specific gymnastic elements to test the gymnast's motor learning ability and to predict future results for top-level athletes. The authors, to better measure the learning progression, utilized specific tests, which were able to distinguish between elite and sub-elite athletes (BenOunis et al., 2013) and the potential of talented gymnasts to develop. Even if the general coordinative traits should be assessed with non-sport specific tests, which are useful to select lower level athletes (Vandorpe et al., 2012), an high correlation between lower and upper limb kinesthetic discrimination, and cadets 2011, 2012, 2013 scores and ranking was found. Orientation shuttle run test significantly correlated to 2012 and 2013 junior championship scores, highlighting that this test is based not only on coordination, but also strength and rapidity, showed only by junior gymnasts.

Precision in the learning process, evaluated by specific tests, predicts talent outcomes better than coordination ability assessed with standardized and validated tests, because rhythmic gymnastics bases gymnastic preparation on the repetition of technical elements until perfect execution is attained. The variability in coordination tests found in this study highlighted that Hirtz's battery (1985) do not seem to be sensitive enough to discriminate gymnasts at the top level. The precision in skill acquisition characterizes expert performance in almost all sport activities (Abbot and Collins, 2002; Ericsson et al., 1993) and plays an essential role in achieving relevant results in rhythmic gymnastics (Kioumourtzoglou et al., 1997; Miletic et al., 2004). The ability for new motor element acquisition is minimally impacted by training, age, and maturation. A high motor learning and coordination ability in new element acquisition were not significantly affected by a gymnast's background experience (such as technical coaching and increased competitive standard), which could lead to an uncorrected talent selection. Vandorpe's (2012) and Abernethy's (2008) research results supported the present findings.

When considering 2011 and 2012 championships, precision showed low predictive value on gymnast scores especially for elite and sub elite cadets. The higher correlation between motor learning assessment and competition results in 2013 rather than in 2012 and 2011 indicated that the predictive power of this indicator grows over time, underlining the potential attainment of long-term expertise. This selection procedure answers to a dynamic conception of talent detection in which learning and adaptation should be viewed as the extreme characteristics of a talented athlete (Ericsson et al., 1993). Trainability and skill learning will allow the acceleration of talent development through additional competition and training opportunities (Vaeyens et al., 2006).

Considering the specific tests one by one, the best technical improvement was found in the most complex tests, such as pivot and 'elements at risk'. These technical elements require greater coordination ability, dynamic balance, multi-limb combination, and orientation than others such as jumps. Jump realization requires improvement in several muscular abilities such as strength and stiffness, which are predictive talent indicators (di Cagno, et al., 2008), but not developed at this age (Weineck, 2009).

Conclusion

In talent identification and selection procedures it is better to include the evaluation of coordination and motor learning ability. Motor learning assessment concerns performance improvement and the ability to develop it, rather than evaluating the athlete's current performance. In this manner talent identification processes should be focused on the future performance capabilities of athletes.

The authors presented pilot data to introduce a more holistic and specific long-term method able to identify and select talented gymnasts with predictive competitive success over a period of three years. The present study underlined the advantage of using specific gymnastics tests rather than validated non-specific test batteries. In the field of practice, it could be useful for coaches to include motor learning tests in selection procedures, as objective criteria that could discriminate between elite and sub-elite pre-adolescent gymnasts. Motor learning tests should be added in the first talent selection procedure as maturity independent tests (Vandendriessche et al., 2012), complementing the coach's intuitive observations and judgments (BenOunis et al., 2013).

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Key points

- In talent identification and selection procedures it is better to include the evaluation of coordination and motor learning ability.
- Motor learning assessment concerns performance improvement and the ability to develop it, rather than evaluating the athlete's current performance.
- In this manner talent identification processes should be focused on the future performance capabilities of athletes.

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