Talent in Female Gymnastics: a Survival Analysis Based upon Performance Characteristics

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Abstract

This study investigated the link between the anthropometric, physical and motor characteristics assessed during talent identification and dropout in young female gymnasts. 3 cohorts of female gymnasts (n=243; 6–9 years) completed a test battery for talent identification. Performance-levels were monitored over 5 years of competition. Kaplan-Meier and Cox Proportional Hazards analyses were conducted to determine the survival rate and the characteristics that influence dropout respectively. Kaplan-Meier analysis indicated that only 18% of the female gymnasts that passed the baseline talent identification test survived at the highest competition level 5 years later. The Cox Proportional Hazards Model indicated that gymnasts with a score in the best quartile for a specific characteristic significantly increased chances of survival by 45–129%. These characteristics being: basic motor skills (129%), shoulder strength (96%), leg strength (53%) and 3 gross motor coordination items (45–73%). These results suggest that tests batteries commonly used for talent identification in young female gymnasts may also provide valuable insights into future dropout. Therefore, multidimensional test batteries deserve a prominent place in the selection process. The individual test results should encourage trainers to invest in an early development of basic physical and motor characteristics to prevent attrition.

Introduction

International success in gymnastics requires many hours of dedicated practice [11]. Russell et al. [22] indicate that 8–10 years of preparation is necessary to reach the elite-level in sports. Given that peak performance in female gymnastics is usually reached at the age of 16, a significant amount of deliberate practice is required from a young age, usually commencing around the age of 6. Beside the issue of early specialization in gymnastics, the process of talent identification and development is crucial.

Indeed, research has revealed that multi-dimensional test batteries may be useful to identify talent. A longitudinal study conducted by Prescott examined the identification and development of talent within a mixed ability sample of 48 gymnasts [21]. In this study, potentially prognostic talent characteristics from social-demographic, physical, perceptual-motor and psychological dimensions of performance were assessed in an “initial” measurement session. Performance was assessed 17 months later using a composite index of competitive performance and technical skill acquisition scores. The results indicated that the profile of the young female gymnast is multidimensional. Prescott recommended that information should be analyzed within each dimension of performance before being combined to produce a multi dimensional profile [21]. The physical characteristics were found to be the most prognostic indicators of talent and were recommended for inclusion in both the initial and subsequent monitoring processes. The significant relationship between several anthropometric variables and gymnastic performance are however insufficiently high to predict performance scores on an individual basis. More recently, Vandorpe et al. [26] examined the effectiveness of a multi-dimensional test battery with a combination of anthropometric, physical, coordinative and technical field tests to predict performance level 2 years later. They showed that a combination of anthropometric, physical and coordination tests predicts the future level of performance 2 years later, with coordination playing the largest part in this prediction.
In gymnastics it is important that talent be identified early in the career of the athlete, and therefore a good understanding of the factors influencing the development of the gymnasts is essential. While dropout can be considered as an almost natural selection mechanism in elite sports, research efforts on this topic have mainly focused on psychological aspects and causes of drop out [12,13,27]. According to Petlichkoff, two-thirds of the athletes between 7–18 years withdraw from sports participation each year [20]. Negative experiences such as lack of fun, coach conflicts and lack of playing time are identified as primary causes of dropout [12,13,27]. However, we do not know to what extent physical and motor competence plays a part in the decision to quit sports practice. Butcher et al. recognized that the reasons for dropout at least partially depend on the level and intensity of previous sports participation [6]. An insufficient level of essential anthropometric, physical and coordination characteristics might lead to an early levelling off of the progression curve, leading to the decision to quit a specific sport. However, there is a lack of studies investigating attrition in female gymnastics based on anthropometric, physical and motor coordination characteristics. One previous investigation, however not related to attrition, found a correlation between anthropometric variables and gymnastic performance of 168 female gymnasts (16.5±1.8 years), participating at the 1987 World Championships [8]. A combination of anthropometric dimensions predicted 32–45% of the variance in performance. Claessens and Lefevre also investigated morphological and performance characteristics as dropout indicators in a sample of younger competitive female gymnasts (10.5±2.6 years). The primary finding was that ‘surviving’ female competitive gymnasts were smaller, with a lower body weight, a lower value of subcutaneous fat, narrower hips and broader shoulders than their counterparts. It has also been shown that flexibility, strength and anaerobic endurance are important talent characteristics for delivering good performances [7].

While multi-dimensional test batteries are important for talent identification, they may also be useful for identifying dropout. However, there is a lack of research investigating the link between factors identified in the test batteries and dropout. Therefore the purposes of the present longitudinal study were threefold. First, to compare anthropometric, physical and motor coordination characteristics between gymnasts continuing at a high level and gymnasts dropping out from competition 3, 4 and 5 years after the baseline measurement. Second, to establish the discriminative power for dropout in female gymnastics, using the multidimensional test battery designed by Vandorpe et al. [25]. Finally, to investigate the predictive power of dropout based on critical talent characteristics.

Methods

In this retrospective study young female gymnasts (6–9 years) completed a gymnastics test battery for talent identification. Performance levels were monitored over 5 years of subsequent competition. The results presented in this study are derived from a large investigation examining a total of 756 gymnasts from 81 gymnastics clubs at the highest level (A level). In Flanders gymnasts can compete in 3 competition levels A or I (under 9 years), B and C. The larger investigation tested 7 separate cohorts of gymnasts over 7 years (2008–2014). This study presents the data from 3 separate cohorts (2008–2010) resulting in a total sample of 243 female gymnasts (7.7±0.7 years). Flanders GymFed invited the clubs to delegate their best gymnasts, so the participants in the baseline measurement in this study are already a selected group. The participants trained 9.5±2.5 h a week, in the past 2.8±1.4 year. Including only these 3 cohorts allows for 5 years of retrospective analysis (Supplementary material 1). This study was also part of a broader project (Flemish Sports Compass) that investigated the physical and general coordinative characteristics of Flemish children. The project was conducted in accordance with recognised ethical standards [14] and was approved by the Ethics Committee of the Ghent University Hospital. Written informed parental consent was obtained for all participants.

The anthropometric assessments were conducted following standardized protocols [18]. Height was measured using a portable stadiometer to the nearest 0.1 cm (Harpenden, Holtain Ltd., Crymlyn, UK). Body mass (to the nearest 0.1 kg) and body fat (to the nearest 0.1 %) were determined by means of a bio-electrical impedance scale (TANITA BC-420SMA, Weda B.V., Naarden, Holland). Height and weight values were used to calculate Body mass Index. Bi-acromial diameter and bi-iliocristal diameter (to the nearest 0.1 cm) were measured with a sliding caliper (Holtauin, UK) and both measurements were used to calculate the androgyne index (Tanner index = 3x bi-acromial diameter – bi-iliocristal diameter).

Flexibility was assessed (to the nearest 0.1 cm) using the sit-and-reach test of the Eurofit test battery [10]. Explosive leg power was evaluated with the countermovement jump (0.1 cm), performed with hands on hips, using Optojump (Microgate, Bolzano, Italy) [Cometti & Cometti, 2007]. The knee push-ups and sit-ups tests, following the Bruininks-Oseretsky test of Motor Proficiency-2 procedures [5] were used to assess upper body strength and core stability. Sprinting ability was measured using a 20 m test with sprint times being recorded using Polifemo light photocells with 0.001 s accuracy (Racetime2, Microgate, Bolzano, Italy) [17]. Anaerobic performance was assessed with a one-minute rope jumping test [25].

The KörperkoordinationsTest für Kinder (KTK) [15] is a widely used, valid, and reliable instrument for assessing the general motor coordination of children [2,19,25]. The KTK consists of four subtests: (1) KTKBB walking backwards 3 times along each of 3 balance beams of decreasing width, with a possible maximum score of 72; (2) KTKMS moving sideways on wooden platforms in 20 s with the score being the sum of the number of relocations over 2 trials; (3) KTKJS jumping sideways with 2 feet over a wooden slab for 15 s, with the score being the sum of the number of jumps over 2 trials; and (4) KTKHH hopping for height on one leg over a foam obstacle increasing in height by 5 cm at each step, with a possible maximum score of 78. The raw performance scores of each subtest are transformed into age- and gender-specific motor quotients, together resulting in a general motor quotient (MQKTK). 9 additional basic tests (running backwards, skipping, hopping, shuffle pass, cross steps, bouncing, jumping jacks, tuck jumps, and giant jumps) were judged on a 10-item qualitative scale (i.e., ability to perform the movement, without falling, with a steady rhythm, supported by arm movements, balanced, with confidence, dynamic, without sloppiness, with sufficient amplitude, and seemingly effortless) to determine the basic locomotion skills of the gymnasts, with a possible maximum score of 90. Trained coaches judged these items, and reliability coefficients were high (test-retest 0.94, inter-rater reliability 0.93) [25].
First, descriptive statistics were studied with the threshold and mean scores that were needed to continue gymnastics 3, 4 or 5 years after the entry test was conducted. Second, to establish the discriminative power for dropout in female gymnastics after 3, 4 and 5 years of practice a discriminant analysis was used to investigate the relevant performance measurements (\( \text{Table 1} \)). The grouping variable was continuing or discontinuing gymnastics and the independent variables were the test results obtained from the 5 anthropometrical, 6 physical and 6 motor coordination characteristics. The classification results indicate the correctly and incorrectly classified gymnasts. Gymnasts classified as “survivors” despite dropping out were classified as false positive and gymnasts wrongly classified, as dropouts were considered as false negative. Third, a Survival Analysis [23] was applied to predict the dropout based on the Quartile scores from the different performance characteristics. Kaplan - Meier analysis was used to investigate the dropout rate and the mean survival time. Cox Regression survival analysis confirmed the significant performance characteristics and predicted the hazard ratios for dropout in female gymnastics1.

### Results

Descriptive statistics revealed that the threshold scores for the survivors increased year after year. For example the lowest sit and reach score required for the gymnasts to continue at the highest level was 25.5 cm, 29.0 cm and 31.0 cm, at 3, 4 and 5 years post baseline respectively (Supplementary material 2). This suggests that the baseline results are more exigent for each year that gymnasts continue their sport. Therefore a gradual raise of the threshold scores might be designated to include the possibility of compensating for some of the talent characteristics. The second analysis aimed to discriminate between gymnasts continuing or discontinuing their sport at the highest competition level (A-level). There was a 68.7 % correct classification 3 years after testing the female gymnasts. From the 138 survivors and 110 dropouts, 34 gymnasts were classified false positive and 110 dropouts, 34 gymnasts were classified false negative (\( \text{r can} = 0.452 \) and Wilks' \( \Lambda = 0.796 \) and \( P < 0.001 \)). The gymnasts that discontinued their sport had significantly lower scores for sit and reach; 20-m sprint; knee push-ups; rope skipping; basic skills; MQKTK; KTKMS and KTKHH. After 4 years a 79.4 % correct classification was reported by the discriminant analysis. From the remaining 67 survivors and 176 gymnasts, discontinuing their sport, 15 were classified false positive and 35 false negative (\( \text{r can} = 0.486 \) and Wilks' \( \Lambda = 0.763 \) and \( P < 0.001 \)). The gymnasts that discontinued their sport had significantly lower scores for sit and reach; 20-m sprint; knee push-ups; sit-ups; rope skipping; basic skills; MQKTK; KTKBB; KTKJS; KTKMS and KTKHH. 5 years after the baseline test 87.7 % of the gymnasts were correctly classified. Only 35 gymnasts “survived” and remain competitive at the highest level. A total of 208 peers dropped out; 3 were false negative gymnasts continuing and 27 false positive gymnasts discontinuing gymnastics (\( \text{r can} = 0.419 \) and Wilks' \( \Lambda = 0.824 \) and \( P < 0.001 \)). The discontinuing gymnasts had significantly lower scores for 20-m sprint; counter movement jump; knee push-ups; sit-ups; rope skipping; basic skills; KTJKS and KTKHH. The classification rates, i.e., the percentage of correctly classified gymnasts, increase for each additional year the gymnasts continue or discontinue their sport after the initial testing (\( \text{Table 1} \)).

Finally, Survival Analysis was applied to predict the hazard ratio for each of the investigated talent characteristics using the cohorts 2008, 2009 and 2010 (n = 243). Kaplan-Meier Survival Analysis revealed that only 17.6 % of the young gymnasts that performed the baseline test survived 5 years of high-level competition. The mean survival time of the 3 investigated cohorts

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1 Survival/failure analysis is a family of techniques dealing with the time it takes for something to happen: a cure, a failure, an employee leaving, a relapse, a death and so on. In the present study we use it for attrition in sports. Tabachnick and Fidell (2007) generally use the more optimistic definition of survival/failure analysis is a family of survival-analysis techniques, different procedures are used depending on the nature of the data and the kinds of questions that are of greatest interest. There are 2 major types of survival analyses: (1) life tables (including proportions of survivors at various times and survivor functions, with tests of group differences) and (2) prediction of survival time from covariates most often involves the Cox proportional-hazards model (Cox regression).
was 2.5 years (95%; 2.18–2.76 years). Cox Regression revealed that basic motor skills and knee push-ups were significant (p < 0.01). Girls with a score < 68 for the motor basic skills increase their chance for dropout by 129% in relation to the girls with a score > 82 (Fig. 1).

The hazard ratio can be found in the Exp (B) column for Quartile 1 (basic skills = 2.291) in Table 2. This means that in relation to quartile 4 which always = 1.000, there is a 129.1% higher hazard rate. Furthermore, girls performing less than 24 knee push-ups increased their chance for dropout by 91.3% compared to girls performing more than 31 knee push-ups. An additional 5 measurements were also significant (p < 0.05). A 20-m sprint greater than 4.276 s increased the hazard ratio by 67.6% compared to sprint performed in less than 3.902 s; a counter movement jump < 18.8 cm increased the chance to discontinue gymnastics by 53.4% compared to a score > 23.8 cm; For KTKBB a score lower than 57 increased the chance for dropping out by 63.0% compared to a perfect score of 72; the KTKHH increased hazard rate by 73.2% for girls scoring less than 56 points in comparison with gymnasts scoring more than 72 points and finally MQKTK < 123 increased the chance to discontinue by 45% compared to a score > 138.

Table 2 Quartile scores with Cox regression hazard ratios of anthropometry, physical and coordinative characteristics.

<table>
<thead>
<tr>
<th></th>
<th>Total population</th>
<th>Quartile 1</th>
<th>Quartile 2</th>
<th>Quartile 3</th>
<th>Quartile 4</th>
<th>Chi-square df</th>
<th>Sig.</th>
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<tbody>
<tr>
<td><strong>Anthropometry</strong></td>
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<tr>
<td>height (cm)</td>
<td>123.0 (6.1)</td>
<td>&lt;118.9</td>
<td>1.021</td>
<td>122.3–127.3</td>
<td>0.941</td>
<td>127.3</td>
<td>0.173</td>
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<tr>
<td>mass (kg)</td>
<td>22.7 (2.9)</td>
<td>&lt;20.6</td>
<td>0.867</td>
<td>22.6–24.8</td>
<td>0.910</td>
<td>&gt;24.8</td>
<td>1.252</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>14.96 (0.98)</td>
<td>&lt;14.30</td>
<td>0.973</td>
<td>15.00–16.00</td>
<td>1.152</td>
<td>&gt;16.0</td>
<td>1.293</td>
</tr>
<tr>
<td>fat % (%)</td>
<td>15.4 (3.0)</td>
<td>&lt;13.5</td>
<td>0.912</td>
<td>15.5–17.3</td>
<td>1.272</td>
<td>&gt;17.3</td>
<td>4.489</td>
</tr>
<tr>
<td>Tanner index (cm)</td>
<td>63.3 (4.1)</td>
<td>&gt;60.8</td>
<td>0.903</td>
<td>63.3–65.8</td>
<td>0.848</td>
<td>&gt;65.8</td>
<td>1.652</td>
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<td><strong>Physical Characteristics</strong></td>
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<tr>
<td>sit and reach (cm)</td>
<td>32.0 (3.2)</td>
<td>&lt;30</td>
<td>0.902</td>
<td>32–34</td>
<td>1.188</td>
<td>&gt;34</td>
<td>8.153</td>
</tr>
<tr>
<td>sprint 20 m (s)</td>
<td>4.098 (0.267)</td>
<td>&gt;4.276</td>
<td>1.397</td>
<td>3.902–4.081</td>
<td>1.136</td>
<td>&lt;3.902</td>
<td>11.088</td>
</tr>
<tr>
<td>counter movement jump (cm)</td>
<td>21.5 (3.8)</td>
<td>&gt;18.8</td>
<td>1.491</td>
<td>21.3–23.8</td>
<td>1.018</td>
<td>&gt;23.8</td>
<td>11.147</td>
</tr>
<tr>
<td>knee push-ups (n/30s)</td>
<td>28 (6)</td>
<td>&lt;24</td>
<td>1.557</td>
<td>28–31</td>
<td>1.244</td>
<td>&gt;31</td>
<td>13.904</td>
</tr>
<tr>
<td>sit-ups (n/30s)</td>
<td>26 (8)</td>
<td>&lt;21</td>
<td>0.959</td>
<td>26–31</td>
<td>1.256</td>
<td>&gt;31</td>
<td>4.762</td>
</tr>
<tr>
<td>rope Skipping (n/60s)</td>
<td>71 (25)</td>
<td>&lt;54</td>
<td>1.176</td>
<td>71–88</td>
<td>1.017</td>
<td>&gt;88</td>
<td>4.659</td>
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<tr>
<td><strong>Motor Coordination</strong></td>
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<tr>
<td>KTK balance beam (n)</td>
<td>62 (9)</td>
<td>&lt;57</td>
<td>1.630</td>
<td>57–63</td>
<td>1.271</td>
<td>64–71</td>
<td>9.163</td>
</tr>
<tr>
<td>KTK jumping sideways (n/15s) 66 (9)</td>
<td>&lt;60</td>
<td>1.328</td>
<td>60–66</td>
<td>1.204</td>
<td>67–72</td>
<td>1.212</td>
<td>&gt;72</td>
</tr>
<tr>
<td>KTK moving sideways (n/20s)</td>
<td>43 (6)</td>
<td>&lt;39</td>
<td>1.155</td>
<td>39–42</td>
<td>1.016</td>
<td>43–47</td>
<td>0.989</td>
</tr>
<tr>
<td>KTK hopping for height (n) 62 (9)</td>
<td>&lt;56</td>
<td>1.732</td>
<td>56–61</td>
<td>1.283</td>
<td>62–70</td>
<td>1.250</td>
<td>&gt;70</td>
</tr>
<tr>
<td>KTK MQ (n)</td>
<td>130 (10)</td>
<td>&lt;123</td>
<td>1.151</td>
<td>131–138</td>
<td>0.924</td>
<td>&gt;138</td>
<td>8.039</td>
</tr>
<tr>
<td>basic skills (n)</td>
<td>75 (11)</td>
<td>&lt;68</td>
<td>1.669</td>
<td>76–82</td>
<td>1.438</td>
<td>&gt;82</td>
<td>26.170</td>
</tr>
</tbody>
</table>
Discussion

This study investigated the link between performance characteristics assessed during talent identification and dropout in young female gymnasts. Kaplan-Meier analysis revealed that only 18% of the female gymnasts starting with the baseline test at the age of seven continued competition at A-level until the age of 12. Six gymnasts continued at the highest competition level in Flanders (junior level A), with 2 qualifying for the European Team Finals in 2014. Gymnastics managers would consider 2 world-class gymnasts in each cohort as a successful outcome of a talent identification system. However, from the 91 participants that were tested in the first cohort, 93.4% of the gymnasts (i.e., 85 gymnasts) do not attain the highest competition level. The displayed results from the Cox Proportional-Hazards Model explain that gymnasts with a score in the best quartile increase their chances to survive between 45% and 129% for basic motor skills (129%), knee push-ups (91%), KTKHH (73%), 20-m sprint (68%), KTKBB (63%), counter movement jump (53%) and the gross motor coordination measured by MQKTK (45%). Although, considering the basic motor skills test as a motor coordination assessment, it is clear that this test is most closely related to the basic needs of gymnastics, which explains the higher hazard ratios. However, the low hazard ratios for anthropometric characteristics can possibly be explained to the natural selection that occurs early in the career. According to Vaeyens et al. [24] excellence in sport is not idiosyncratic to a standard set of performance attributes. It can be achieved in individual or unique ways through different combinations. This effect has been termed the "compensation phenomenon". When comparing Table 1 with the outcomes of the discriminant analysis and Table 2 with the outcomes of the survival analysis it is clear that the survivors do not necessarily score in the best quartile (Q4) for each of the significant talent characteristics. Therefore, compensation may be possible between the different variables. For example the surviving gymnast with the lowest MQKTK (score = 123; Q4 > 138) compensated this low score with superior scores for sit and reach (score = 34; Q4 > 34); 20-m sprint (score = 3.717; Q4 < 3.902); counter movement jump (score = 28.7; Q4 > 23.8); knee push ups (score = 34; Q4 > 31); KTKBB (score = 72; Q4 > 71); KTKHH (score = 78; Q4 > 72); and basic motor skills (score = 96; Q4 > 82). Disengaging from gymnastics is a multi-dimensional process, with single factors unable to determine dropout [16]. Indeed, the decision to end a career might be the outcome of severe physical and mental exhaustion in older gymnasts (18–22 years), resulting from heavy training at an early age [16]. According to previous research, athletic failure in gymnastics does not appear to be an important factor for the disengagement process [7,16]. Contrastingly, the present study highlights that low scores for performance characteristics could be influential in the decision to withdraw from gymnastics competition. The discriminant analysis reveals that gymnasts do not last longer than 3 years in their sport when scoring low for flexibility, speed, strength, basic motor skills and gross motor coordination. In addition, the descriptive statistical analyses show that for every year that gymnasts continue their sport, the lowest score of the survivors increases. This suggests that the baseline results are more exigent for each year that gymnasts continue their sport. Therefore a gradual rise of the threshold scores of some characteristics might be designated to include the possibility of compensating for other talent characteristics. This outcome promotes the use of these tests for talent identification at a young age and for identifying specific training needs at all ages (Supplementary material 3: examples of score sheets for TID). Although the test battery used in this investigation was quite extensive, it may be limited by the absence of important psychological [1] and environmental factors [4,9]. In our opinion the lack of a psychological assessment is more important in a second phase, when gymnasts decide to start with a thorough training schedule. This generally occurs at the age of 12, when the best gymnasts are selected for development at elite schools. Considering the high dropout rate before reaching this point, it seems plausible to invest in a brief assessment of psychological and environmental characteristics at a younger age to prevent this early attrition.

The high amount of withdrawals at the highest competition level observed in this investigation should encourage gymnastics managers to focus on the competencies of the children, guiding them to another gymnastic discipline in which they can excel. In this way, the test battery should not only focus on identifying for artistic gymnastics. Indeed, diversified involvement in a number of sports during early stages of development has been presented as a possible alternative to early specialization [3]. Therefore, a variety of different gymnastic disciplines not only provide opportunities for a complete gymnastic development but also for orientation towards complementary gymnastics disciplines. Rhythmic gymnastics could be an option for the most flexible gymnasts and trampoline and tumbling for the better jumpers. The dropout rate in female artistic gymnastics is unusually high. It is also likely that parents play an important role in the decision to invest these large amounts of training time, with possible impact on academic performance as well. Since elite gymnastics has only very limited financial reward, choices towards this high-load sport are probably less evident, and investment in academic success is preferred. Only one female gymnast out of 5 survives 5 years of competition in this demanding sport, requiring 30 h of training per week. Performance characteristics appear important for identifying talent and potential dropout. Therefore, an identification test battery should not only provide selection criteria but also focus on possible transitions to other gymnastic disciplines or even other sports. Only the gymnasts with the very best profile on “most” performance-related parameters or best compensators are those that might have the highest chance of keeping up the high load as they get the better progress from their training efforts. The results should also encourage gymnastic trainers to invest in early development of basic physical and motor characteristics to prevent a complete attrition from sports participation.

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