CONSIDERATIONS FOR CONTROLLED COMPETITION LANDINGS IN GYMNASTICS: AGGREGATED OPINIONS OF EXPERTS

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Abstract

Dismounts from apparatus containing multiple rotations, performed by elite gymnasts during competition, require great courage and virtuoso displays of precisely organized movements and skills. The dismount and landing leave the final impression in a routine and are often the key to a successful evaluation by the judges. Landings require precise body control and the skillful dissipation of substantial body momentum. The aim of this research study was to investigate landing techniques and strategies used by elite male gymnasts through the eyes of gymnastics experts. It drew from the accrued knowledge and experience of 21 male expert participants who were elite coaches, elite gymnasts, international judges or combinations of these. The experts made a number of subtle points, many of which are not in the extant literature. The experts highlighted concerns about safety and the study concluded that on-going monitoring of the rules on competition landings within the Code of Points (Fédération Internationale de Gymnastique, 2015) would be beneficial to the sport.

Keywords: *controlled competition landings, landing technique, landing strategies, optimal body segment coordination.*

INTRODUCTION

Arguably, the most important and crucial part of gymnastics routines is the landing which signals the termination of the routine and leaves a final impression in the minds of the judges.

For instance, Takei and Dunn (1997) suggest that an expertly executed dismount ending with a well-controlled landing may persuade judges to be more lenient and deduct fewer points for technical mistakes made earlier in the routine. Competition landings occur at the end of routines on all apparatus with the exception of the floor exercise, where landings occur frequently but also include a final landing. Landings in gymnastics are expected to be controlled, thus enabling the performer to land safely without incurring injury. Gymnasts must meet the specific landing performance criteria imposed by the International Gymnastic Federations' (Fédération Internationale de Gymnastique [FIG], 2015) Men's Technical Committee's Code of Points for men's artistic gymnastic competitions. According to Article 9.2, Point 16 in the Code: for safety reasons a gymnast may land and or dismount with their feet apart (enough to properly join their heels together) upon landing from any salto. The gymnast must complete the heels together without lifting and moving the front of his feet. This is done by raising the heels off the mat and joining them together without lifting the front of the feet. The arms must also be in complete control with no unnecessary swings (p. 31)

The successful achievement of controlled competition landings is contingent on the correct positioning of the extended body position during flight in preparation for landing. To obtain a good score from the judges, the gymnast must absorb the impact forces of the dismount without losing balance or moving their feet during the landing. A controlled competition landing results as the product of the process of a gymnast consciously and deliberately reducing all body momenta, either from a dismount off apparatus or from an acrobatic tumbling skill on floor, over time to zero, terminating with a single simultaneous placement of both feet. This process should occur with a visually controlled upright body position, exhibiting symmetry of the whole body and its segments, performed in a rhythmical, harmonious, safe and aesthetic manner, from landing touch-down to landing minimum, and resulting in a final stand-still position (Geiblinger, 1998; Gittoes, Irwin, & Kerwin, 2013).

The aim of this research study was to investigate the landing techniques and strategies used by male gymnasts. It draws from relevant literature, discussions and questionnaires from 21 male participants consisting of elite coaches, elite gymnasts and international judges.

Although there is abundant experimental, laboratory-based and theoretical research on landings in general, the complex and multiple strategies utilised by gymnasts during competition landings are well documented (Cuk & Marinsek, 2013; Gittoes & Irwin, 2012; McNitt-Gray, Hester, Mathiyakom, & Munkas, 2001; McNitt-Gray, Requejo, Flashner, & Boni, 2004; McNitt-Gray, Yokoi, & Millward, 1994; Prassas, Young-Hoo, & Sands, 2006), there are still weaknesses in the literature concerning landing techniques and strategies that could be strengthened by accessing the accumulated knowledge of gymnastics experts.

Geiblinger (1998) reported that the interplay of the angular velocities between the ankle, knee, hip and shoulder joints, and the temporal patterns of the kinematic chain, which enables the subject to displace the centre of mass at will in order to maintain balance and stability during the landing process, are crucial in the production of an optimal landing performance.

Most dismounts include multiple somersaults or twists, and often both. Prassas et al. (2006) report that for gymnasts to successfully perform rotational skills, it is crucial to control angular momenta resulting from somersaults or twists. When performing dismounts, the gymnast must generate sufficient angular momentum to execute the number of somersaults and twists required by the skill, and also attain enough height for sufficient air time to complete the rotation. The transfer of angular momentum from the body to the body segments can slow down the rotation of the gymnast’s body, thus increasing the possibility of a successful landing. The most challenging landings, which follow difficult three-dimensional rotational skills, have a maximum force of seven times the body weight for the giant swing prior to release, with maximum heights from dismounts recorded in excess of four metres (Alp & Brüggemann, 1993; Brüggemann, Cheetham, Alp, & Arampatzis, 1994; Geiblinger, 1998; Gervais, 1993). Fink (2009) states that during landings, forces are applied – not absorbed – to reduce all momenta to zero. A body that is tilted due to twisting must be un-tilted prior to landing. Residual rotation after touch-down can be reduced by intersegmental transfer of angular momentum, in this instance by circling the arms in the direction of the undesired rotation.

Only a low proportion of competition landings are successful and the main reason for this is landing asymmetries (Cuk & Marinsek, 2013). The key predictors for these asymmetries are differences in vertical hip velocity, ankle angle position, knee angle change, the difference in ankle angle between the legs in the lowest position, knee angle change of the non-leading leg from the first contact, and the difference in knee angle between the leading and non-leading leg at first contact (ibid.). In almost all successfully balanced landings, ground contact occurs with the CM position above the feet and between the toe and heel, because the linear impact impulses that stop the feet also contribute to an angular impulse that slows angular momentum (Sheets & Hubbard, 2007). In the case of the largest pre-impact angular velocities, for example following a double-somersault dismount, contact occurs with the CM in front of the toe. The gymnast is in a balanceable pre-impact orientation longer when rotating more slowly and with a smaller angular momentum, therefore balance will be more likely after performing a single-somersault dismount with a large moment of inertia (ibid.).

Landings cause great stress to the lower extremities and can generate reaction forces up to 10 times bodyweight leading to an overload of the lower extremities and causing overuse injuries (Kerwin, Yeadon, & Lee, 1990). Brüggemann (1990) suggests that it is important for landings to be practiced on different surfaces, therefore the gymnast must learn to adapt and train the tension of the leg extensor muscles to the specific landing situations which are environment (landing surface) and skill performance dependent. Chapman (2008), P. Perez, Llana, Klapsing, J. Perez, Cortell, and Van Den Tillaar (2010), and McNitt-Gray, Yokoi, and Millward (1994) indicate that gymnast-mat interaction, the gymnast's ability, and mat properties (such as surface and thickness) each influence shock absorption and stability, and therefore play an important role in achieving a successful landing.

Successful landings are performed with a high level of body stiffness in the first part of the landing with a knee angle greater than 63 degrees and, for a soft landing, an angle of less than 63 degrees (Cuk & Marinsek, 2013). Gymnasts are exposed to a high incidence of impact landings due to the execution of repeated dismount performances during training which can potentially lead to overuse injuries in the lower extremities (ibid.). Lees (1981) and Nigg (1985) reported that landing techniques permitting greater knee flexion reduce the vertical load and peak impact force transmitted to the joints and that hard landings are characterised by minimal joint flexion, whereas soft landings permit greater joint flexion.

The ability to accommodate unexpected events and distribute loads between musculo-skeletal structures is of great importance when gymnasts repeatedly perform difficult skills at high velocities. In landings after somersaults on the floor, considerable reaction forces and segmental accelerations occur. Gymnasts tending to perform over-rotated landings may benefit from flight phase control strategies that reduce the rate of total body rotation or redistribute angular momentum among the body segments such that the initial conditions at touch-down are conducive for controlling momentum during contact (Requejo, McNitt-Gray, & Flashner, 2004).

Landing errors on the floor are often caused by wrong decisions during the flight phase. Marinsek and Cuk (2010) investigated the characteristics of somersault landings performed by 97 senior gymnasts and found that axis of rotation, number of turns about the longitudinal axis, and initial landing height have a significant impact on the magnitude of landing mistakes, and that neuromuscular control plays an important role in landing performances.

Dismounts from the horizontal bar require the dissipation of substantial velocities and, therefore, large forces. Kerwin, Yeadon, and Harwood (1993) provide a detailed description of the release phase and its importance in the correct release timing for triple back somersault dismounts. They reported that body angles at the moment of release are important factors to landing difficult dismounts successfully. It is therefore necessary for a gymnast to have several strategies of preparatory giant swings for the execution of different dismounts.

Takei, Nohara, and Kamimura (1992) examined the techniques used by elite gymnasts at the 1992 Olympic Games in the compulsory dismount from the horizontal bar. They reported that successful dismount performance is more likely when gymnasts have a large vertical velocity at bar release, which ensures optimal height and flight time, so that they can maintain an extended body position during the remainder of the flight to display body style for virtuosity bonus points, and to simultaneously prepare for a controlled landing. Because of the large landing impact forces during the landing process from the horizontal bar, the forces have to be dissipated over a relatively long time through greater knee and hip joint flexion. Takei and Dunn (1997) suggest that a full body extension, completed early during the second salto (in a double salto tucked) well above the bar, serves two purposes: first, due to the conservation of angular momentum, it brings about a small and steady angular velocity; and second, it provides an opportunity for the gymnast to spot the point of landing and prepare for a controlled touch-down on the landing surface.

Gymnasts are more stable at landing under conditions that allow them to spot the floor during either the entire backward somersault or the last half of the forward somersault (Davlin, Sands, & Shultz 2001; Luis & Tremblay, 2008). Visual feedback during a back tuck somersault is used for improving landing stability at all angular head velocities, but optimal feedback occurs when retinal stability is achieved as the head is held still. Low landing success may be attributed to the gymnast's reduced ability to obtain the kinaesthetic feedback necessary for spatial orientation to spot the mat as early as possible in the landing phase in order to make necessary adjustments (McNitt-Gray, Hester, Mathiyakom, & Munkas, 2001).

In summary, the literature shows considerable effort has been expended in the pursuit of scientific study of various aspects of landings, yet comparatively little effort has been made to access the accrued wisdom and experience of gymnastics experts and their opinions about achieving safe and successful competition landings.

METHOD

The expert participants in this study were 21 males consisting of elite gymnasts, state, national and international coaches, and FIG-accredited international judges. Accordingly, they were elite gymnasts, coaches, judges or, in some cases, all of these. The criteria used to select these participants was based on their status and standing in the Australian and wider international gymnastics community. The Australian gymnastics community includes international experts from Europe, Russia, China and the USA. These expert participants had valuable lived experiences and expertise pertaining to competition landings, thus a qualitative methodology was used to investigate their experience, expertise, perception and beliefs how competition landings should be performed. Such an approach is recommended for the qualitative investigation of beliefs and understandings (Cresswell, 2009). A key component within the methodology was conducting expert interviews. As Bogner and Menz (2009) explain, the expert interview is a powerful social research tool for exploring expert knowledge that is typically codified, systematized and combines theory and practice.

Data were gathered from questionnaires with all the experts and follow-up interviews with eight of the experts. The questionnaire was constructed from information derived from a theoretical biomechanical model of the release, flight and landing phases experienced by elite gymnasts (Geiblinger, 1998). This model shows how the various determinants are related to each other and how each parameter is determined from the release phase through to completion of the landing. It represents how the landing develops both spatially and temporally. The questionnaire was structured so that the experts could provide detailed recommendations for gymnasts' body and body segment positioning and actions. The interview served the purpose of verifying and triangulating the questionnaire data.

The study was conducted in the Australian context. Interviews with the experts were conducted at the Queensland Academy of Sport and the Australian Institute of Sport. The interviews investigated the experience, expertise, beliefs and understandings from the perspectives of the experts. Also, short-answer format questionnaires consisting of 16 questions were emailed to the experts in Australia and overseas. Participation was voluntary and identities were kept anonymous. The responses from the experts for each question from the short-answer format questionnaire were analysed and then converted into key summary statements (see Table 1). These key **s**ummary statements, collated from the aggregated responses from the experts, were then synthesised and presented in sequential order according to the landing process.

The first author had insider researcher status (Crotty, 1998; Geiblinger, 2009) because he had an expert knowledge and understanding of the research context. His background as an international gymnast, coach, FIG-accredited judge and scientific researcher, at five world gymnastics championships spanning a period of over 20 years, along with his professional knowledge and understanding of how the human body functions and works, gave him considerable credibility with the expert participants (Bognor & Menz, 2009; Littig, 2009). This not only ensured a high level of participation and compliance in the project, it also strengthened the validity of the method and confers added authority to the recommendations provided at the end of this study.

RESULTS

The results of this study present the combined opinions of the experts on techniques, strategies and considerations for controlled competition landings. The responses from the experts for each question were analysed and aggregated and then presented as key summary statements (see Table 1). The experts' opinions had a high degree of agreement. This was apparent in both the responses to the questionnaires and the interviews which were used to verify and triangulate the data.

The landing phase of the competition routine relates to the temporal and spatial parameters from initial contact (first foot contact or touch-down on the landing surface) of the CM to the CM minimum position during the landing. This point in time is theoretically associated with the time the velocity of the CM becomes zero. Subsequently, the gymnast returns to a standstill position (Geiblinger, 1998). The following description for a successful competition landing from the experts' perspectives is synthesized from excerpts from the key **s**ummary statements:

- Successful achievement of controlled competition landings is contingent upon the correct positioning of the extended body position during the flight phase in preparation for landing.
- Preparation for the landing should include skilled execution of the dismount with hips slightly flexed but segment joints extended and tight but not stiff.
- At landing touch-down, the body position should change from an extended body position gradually flexing, symmetrically and square to the direction of travel.

Table 1
Key summary statements on competition landings from aggregated responses.

Questions	Key summary statements
1. How should a gymnast perform a competition landing?	The gymnast should perform the landing so that there are no point deductions, exhibiting a straight back with straight shoulders, head in a neutral position but ‘spotting the floor’, arms held oblique at approximately 45 degrees, hips and knees flexed with knees shoulder-width apart over toes, feet turned slightly outwards with control, and ankles slightly plantar flexed. Energy is absorbed, speed is slowed and the gymnast flexes more. Once the rotation and linear motion is stopped, the gymnast stands erect with arms out sideways and approximately 30 degrees above horizontal. The gymnast remains stationary for several seconds to demonstrate control of the landing.
2. What does a perfect landing position look like?	A perfect landing position should be balanced from a stretched position with knees together (knees pressed together is for “strong” legs) and feet slightly apart to a weightlifting set-up position with buttock out square and straight, with the head straight in a neutral position and spotting an object. Presentation is very important, esthetically pleasing, straight body alignment as in ballet.
3. How should the arms be positioned at landing touch-down?	The arms should be downwards, close to the body, strong and tight arms to absorb energy, generally in front and to counter rotation up or down.
4. How should be the arm movement during landing?	The arm movement during the landing should be downwards, close to the body, strong and tight and no arm movement. It was also suggested that a counter arm movement sideways and upwards with ‘tight and strong arms’ may occur.
5. How should the arms be positioned at completion of landing?	The arms should be sideward up about 30-45 degrees oblique, aesthetic looking with shoulders down.
6. How should the head be positioned at landing touch-down?	The head should be ideally straight in a neutral position or slightly forwards and flexed at the neck.
7. How much should the legs be bent during landing?	The legs should be bent according to the difficulty and height (vertical velocity) of the dismount and flexibility of the gymnast; generally at about an inside angle 135 degrees or a bit less.
8. How much should the hips be bent during landing?	The higher the dismount, the more hips should be bent; depends on many factors but generally about 30 degrees of forward lean.
9. How should the body position be at landing touch-down?	The body position at landing touch-down should be from an extended body position gradually flexing, square and straight upright with the head straight in a neutral position and spotting an object. Back should be straight and as the dismount is higher the more forward the body position. Gymnast’s personal preference of knees together or apart. Just before touch-down everything slightly bent and prepared for landing. During landing ankles 60 degrees, knees 90 degrees, hips 90 degrees, arms parallel to floor.
10. How should the body position be at completion of landing?	The body position at completion of the landing should be upright and straight body alignment (as in ballet) with arms sideward and head straight. Aesthetic looking is very important, as in the letter Y.
11. What should be the preparation before landing?	The preparation before the landing should have a good execution of the dismount skill before the landing, the body slightly bent with joints extended and tight but not stiff.

12. Are there any visual cues you give to gymnasts?	Visual cues for a gymnast are important by spotting the floor (backward rotations) or spotting a wall (forward rotations). On landings from backward somersaults or front somersaults with a half twist, the gymnast should spot the ground. On forward landings the gymnast senses where he is and spots the wall or whatever is in front and above. All somersaults must be spotted and sensed.
13. What should the tempo be of a landing?	The tempo of the landing should be fast but with control, for example, land, hold squat, and stand up in to a Y-position (0.5 seconds each). It depends on the dismount skill before the landing. The landing must absorb the energy of the fall and the somersault. It is rapid at first but slows down as the speed is decelerated coming to a final stop in the bent position. The gymnast then stands to the upright position. This should be done in a confident manner, not too slowly.
14. Any Floor specific landing instructions?	Floor landings are more difficult because of the springiness of the floor, landing a little earlier (short) before somersault is completely finished to absorb horizontal velocity. Tumbling causes fast somersaults sometimes with a large horizontal velocity. This means that the landing point of the feet should be further away from the centre of gravity in order to allow the gymnast to stop the travel without stepping forward but not too far so as to avoid falling back.
15. Any Horizontal Bar specific landing instructions?	Horizontal bar landings require arm action to be 'stronger' and closer to the body and more hip and knee flexion because of greater vertical velocity, dismount parameters (rotations, body position extended) should be finished before landing.
16. Any other points?	General points on successful landings were: • Gymnast to develop with their skill level, to develop their own landing technique and strategies that are progressive with gymnast's development. • In front landings, gymnast needs to avoid landing on the heels as that will cause excessive force to be transmitted into the lower back and may cause injury. Similarly, back landings should be on toes (balls of the feet) first, dorsi-flexing in a controlled manner. • Aerial awareness is very important and landing drills on trampoline such as sticking the landing from saltos forwards and backwards and double saltos with and without twists, should be practiced. The gymnast needs to land properly every time, also in training. This should be taken further to the next level by practicing 'blind' landings' for kinaesthetic awareness. • Always focus on a good landing position even when doing basic skills and particularly, when landing on training surfaces such as foam rubber pits or soft landing mats. • Position knees together, feet slightly apart, arms parallel and strong and be ready to take one small step immediately rather than waiting and being forced to take a large step. If the skill is difficult, keep the arms as close as possible to the body which enhances the ability to make adjustments. • Always remember toes, fingers, hands, arms and posture at all times, not only in dismount and landing, but also in presentation. • Quality of dismount execution before landing. Insufficient training for difficult dismounts is detrimental to landing performance and a potential source of injury. • Physical fitness is important, for example, to have strong legs – in particular at the end of a routine. Develop more ankle flexibility, range of ankle flexion (dorsi-flexion).

- The head should ideally be straight in a neutral position or slightly forwards and flexed at the neck and spotting an object such as the floor or a wall. Visual cues for a gymnast are important by spotting the floor when performing back somersaults (backward rotations) or spotting a wall when performing forward somersaults (forward rotations).
- On forward landings, the gymnast can sense where he is and spot the wall or whatever other object is in front and above. All somersaults must be spotted and sensed (kinesthetic awareness).
- During landing, the arms should remain downwards, staying close to the body, strong and tight with no arm movement.
- The hips should generally be flexed at approximately 30 degrees. However, the higher the dismount, the more hip flexion is required to absorb impact velocity.
- The knees should be flexed according to the difficulty level and height (vertical displacement and velocity) of the dismount and flexibility of the gymnast, generally approximately 45 degrees, knees pressed together (for “strong” legs) and feet slightly apart as in a weightlifting set-up position with buttock out square and straight.
- In front landings, avoid landing on the heels as that will cause excessive forces to be transmitted into the lower back and may cause injury; back landings should be on toes and balls of the feet, dorsi-flexing in a controlled manner.
- The tempo of the landing should be fast but with control, for example, land, hold squat, and stand up in to a Y- position (0.5 seconds each). It depends on the complexity and difficulty of the dismount skill before the landing. The landing must absorb the energy by reducing all body momenta. It is rapid at first but slows down as the speed is decelerated coming to a final stop with hip, knees and ankle joints in a flexed position.
- At completion of the landing, the gymnast stands up to a still position. The gymnast should be upright with straight body alignment with arms sideward and head straight. This should be done in a confident manner, not too slowly. Presentation is very important and should be aesthetic and artistic. The gymnast remains stationary for several seconds to demonstrate control of the landing.

Additional considerations were:

- Floor landings are more difficult because of the springiness of the floor, landing a little short before the somersault is completely finished to absorb horizontal velocity.
- Horizontal bar landings require arm action to be ‘stronger’ and closer to the body with more hip and knee flexion because of greater vertical velocity.
- Other general points on successful landings were reported by the experts. These include: (a) focus on a good landing position even when doing basics, including during training; (b) land with knees pressed together, feet slightly apart, arms parallel and strong; (c) keep the arms as close as possible to the body if the skill is difficult. The ability to adjust body and segment position at an instant is essential; (d) be mindful of toes, fingers, hands and arms position and body posture at all times not only in dismount and landing but also in presentation; (e) gymnasts should develop their own landing strategies and technique that are progressive with gymnast’s development; and (f) quality of dismount execution before landing is important. Insufficient training for difficult dismounts is detrimental to landing performance and a potential source of injury.

DISCUSSION

Our findings indicate that successful attainment of controlled competition landings is likely when efforts are made to achieve optimal release conditions, optimal rotational flight requirements, and optimal body segment coordination and timing during the landing phase. Accordingly, factors that must be considered when investigating the landing process include: competition landing technique, landing strategies, body segment coordination, reduction of velocities, landing height, angular momentum, impact forces, reaction time and anticipation, balance, coordination, orientation, quickness, temporal and spatial parameters, proprioception and kinesthetic awareness, physical fitness, symmetry, postural adjustment before action, and sensory contribution, specifically during the landing.

The expert participants provided detailed descriptions concerning precise body and body segment positions as well as discrete and accurate actions from the moment of dismount release through to completion of the landing phase. This is congruent with Prassas et al. (2006) who indicated that biomechanics is well suited to examine, describe, develop and improve technique. Some of the experts' opinions have been reported in the extant literature but others are unreported.

Some of the similarities between the experts' opinions and the literature were: (a) landing performance such that there are no point deductions; body and segmental positioning; body stiffness at landing touch-down (Cuk & Marinsek, 2013); (b) high velocities and impact forces (Prassas et al., 2006); (c) safety issues and past injuries such as ankles or feet (Cuk & Marinsek, 2013); (d) mat properties (Brüggemann, 1990; Chapman, 2008; Perez et al., 2010); (e) environmental conditions, vision and spotting (Davlin, Sands, & Shultz, 2001; Luis & Tremblay, 2008); and (f) other factors such as the quality of landing surface, influence successful landing performance.

In order to implement corrective landing strategies, the gymnast may employ actions such as rotating the arms, using the transfer of angular momentum principle by transferring angular momentum from the body to the upper extremities, or excessively flexing the hips or knees to decrease the ground reaction force braking the body and subsequently increases the landing time (Prassas et al., 2006).

Some of the differences between the literature and the experts' opinions included: (a) a perfect landing position should be balanced from a stretched position with knees pressed together for 'strong' legs with feet slightly apart as in a weightlifter's 'set-up' position with buttocks out, body squarely aligned and straight, with the head straight in a neutral position and spotting an object; (b) at landing touch-down, the arms should be downwards, close to the body, with 'strong and tight' arms to absorb energy, in front and to counter rotation up or down; (c) once the rotation and linear motion ends, the gymnast stands erect with arms up about 30 degrees above horizontal and out sideways. The gymnast remains stationary for several seconds to demonstrate control of the landing; (d) presentation is important and should be aesthetic and artistically pleasing; (e) physical fitness and dismount skill readiness are important considerations, for example, 'strong' legs at the end of a routine; and (f) landing practice on the trampoline for aerial awareness is important for sticking landings from somersaults (saltos), both forwards and backwards, and double saltos, with and without twists. The gymnast needs to land properly every time, including in training when recovery practice from 'bad' landings should occur along with practicing 'blind' landings for kinaesthetic awareness.

Many of the expert participants had concerns about the prevalence of injuries during competition landings (Gittoes & Irwin, 2012). The risk of injuries and other safety concerns were considered to be issues by the experts, specifically the coaches and gymnasts. The experts commented that greater consideration should be given to improving landing technique due to the undue risk of injury during competition landings. In addition, gymnasts often carry overuse injuries that are not deemed serious enough to prevent training or competition but are serious enough to affect landing performance and may cause chronic damage to the body and segment joints in the longer term (Cuk & Marinsek, 2013). Other factors such as the quality of the landing surface and past injuries (especially to the ankles or feet) are likely to influence landing performance. In order to "avoid asymmetric landing(s)", gymnasts need to attain sufficient height, generate higher angular momentum around the transverse and longitudinal axes, and have greater control of angular velocity about the longitudinal axis; but to achieve this, they must first "improve their motor abilities and technique" (ibid., p. 31). Over the long term, asymmetric landings can cause acute injuries in the ankles and knees or chronic injuries to the spine (ibid.). These statements are consistent with the experts' opinions on this issue. The most recent version of the Code of Points (FIG, 2015) has an additional focus on safety considerations during landings (see Article 9.2, Point 16 quoted above in the Introduction) but it remains to be seen how much impact this measure will have on reducing injuries sustained during competition landings.

CONCLUSION

This study reveals a tension in the execution of gymnastics landings in regard to aesthetic, execution and safety considerations. Traditionally, aesthetic considerations have predominated but this often leads to situations where gymnasts are injured or perform more conservatively because they are afraid of incurring point deductions. If the sport of artistic gymnastics takes steps to give added weight to safety considerations by reducing or abolishing point deductions for certain competition landing errors, it would enhance the evolution of more difficult, complex and novel dismounts. As the evolution of gymnastics evolves in terms of better landing mats, advances in medical science and improved sports science, it would be logical to encourage the evolution of skills by introducing a wider range of allowable landing strategies that do not incur point deductions.

The findings of this study indicate that greater consideration should be given to the risk of gymnasts sustaining permanent damage associated with deceleration injuries during the landing process. In order to reduce the risk of injury, recent changes to landings in the Code of Points for men's artistic gymnastics should be monitored for the incidence of injury (FIG, 2015). Further changes to landing requirements could include mandating a softer surface with more give in order to reduce the potential for ankle and Achilles tendon injuries. Accordingly, further research that harnesses the accrued knowledge of experts to identify optimal safety parameters for both training and competition landings is worthy of attention.

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