

Alpine Ontario Fitness Testing Fall 2009 – Interpretations and Recommendations of Movement Screen

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Can injuries be prevented? We know that over 90 per cent of all sport medicine injuries are related to the way we move. If we move correctly we can greatly reduce injuries such as knee injuries^{2,3}, non-contact ACL injuries⁴⁻⁶, and low back injuries⁷.

Because of this at Fall AOA testing we started a new and exciting initiative to screen for injuries while improving performance. The key to this initiative is the way we move, and the simplicity in comparing an athlete's movement against a standard.

During Fall Testing athletes were exposed to two tests: the single legged squat and the drop jump screen test. These tests have been researched extensively for the purposes of predicting injury^{1,8}, return to sport protocols⁹, to understand the difference between males and female development, and to evaluate training adaptations¹⁰. At times researchers

have also added electromyography (EMG) analysis¹¹ (to examine muscle activation patterns) 3D motion analysis, video motion, and force plate analysis to further understand how these tests can be helpful for predicting and preventing injuries.

In this report we will examine the results of the single legged squat and drop jump to determine injury risk. We will expose you to the importance of the tests and how movement is the key to injury prevention and performance.

KEY POINTS:

- Movement is key for injury prevention and performance
- Over 92% and 72% of all athletes tested displayed dynamic valgus during the single legged squat and drop jump screen respectively.
- Females display significantly more dynamic valgus during the drop jump than males, 90% vs. 59% respectively.



Figure 1: Dynamic Valgus vs. Ideal during various movements. A) A young female (aged 11) displaying severe inward movement of her knee with ankle collapse and hip shift. Notice that the knee passes across the midline of her body and the other knee is required to prevent the knee from moving inward further. **B)** A young boy (aged 11) displaying moderate to severe dynamic valgus. His feet display over pronation which contribute to his unstable, unbalanced position. **C)** An adolescent female (aged 16) lands with bilateral dynamic knee valgus during a drop jump screen. This is a typical pattern and explains why female adolescent athletes are at an increased risk for non-contact ACL injuries. **D)** A young professional athletes (aged 25) lands after hopping with her left knee displaying moderate dynamic knee valgus with foot toeing out. **E-G)** A young male (aged 15) displaying ideal movements during an overhead squat, squat and single legged squat.

Movement Results for the Single Legged Squat

The single leg squat (SLS) is a movement assessment that helps to predict knee injuries, such as tendopathies^{12, 13}, patellofemoral pain¹⁴,¹⁵, and even non-contact ACL injuries¹². The ability to perform a single legged squat for a skier is critical, because turning in skiing is largely unilateral, based on the strength and power qualities of the downhill leg. Likewise, because the forces exerted on a single leg will exceed 4x body weight during skiing we must be able to perform a SLS with our body weight.

The movement standard for the single leg squat is a parallel SLS with perfect form (5 Site Integrity – see athletic development guide for more information, www.fitstoronto.com/education). Perfect form indicates that our chest remains upright, our spine is in a neutral position, our pelvis does not shift, and our hips, knees, and ankle remain aligned – see Figure 1: Dynamic Valgus vs. Ideal movement. Common movement dysfunctions are dynamic valgus and loss of neutral spine position. Dynamic valgus is the inward

which will be explained in detail in the next section. We have assessed both of these qualities in addition to depth during Fall fitness testing. However due to the nature of this review we will discuss only dynamic valgus and depth.

How we control our knee position determines our susceptibility to injury. We must be able to perform a single legged squat. The standard we believe is suitable for all athletes and individuals are a parallel SLS above 12 years of age. Major factors that determine our ability to perform a SLS are: hip strength in particular hip external rotation and hip abduction, foot and ankle control, and trunk control.¹⁶

We are working on an index to give a concrete value of the hip strength required for each athlete to achieve the SLS movement standard. By creating this index we can give a quantified value to help motivate athletes and to give strength and conditioning coaches a target to achieve during training.

Dynamic valgus – Inward knee movement.

Single Legged Squat

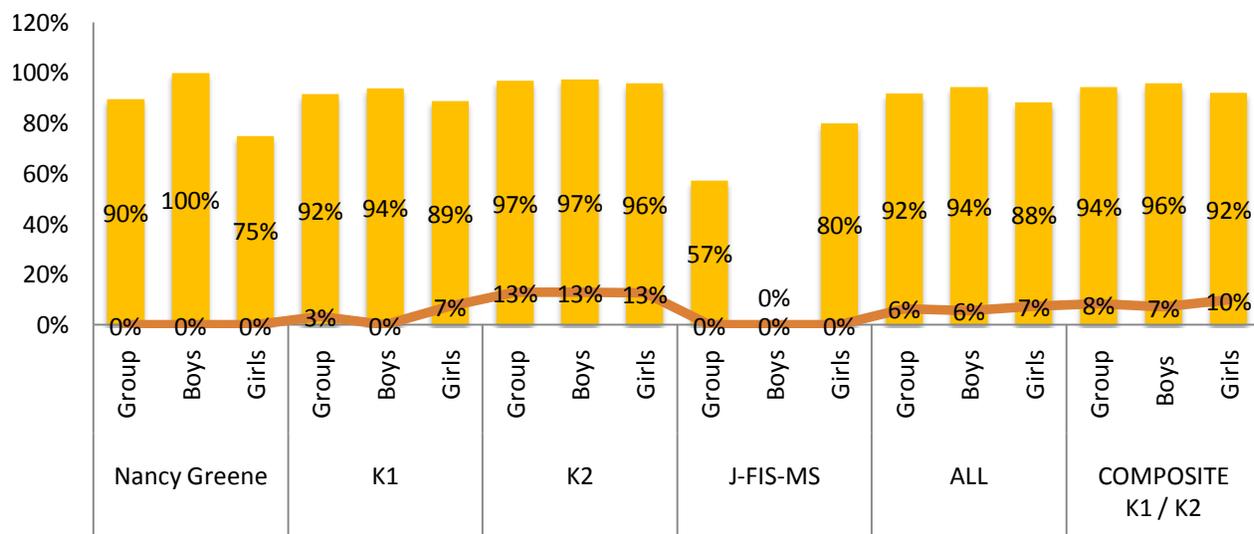


Table 1: Athletes displaying dynamic valgus and able to achieve movement standard by competition level

movement of the knee during movement,

Dynamic valgus is a term used to describe when the knee collapses inward during movement. This finding represents the knees inability to maintain its dynamic integrity (position during movement) while under load representing poor body control, weakness of the hip musculature^{13,16}, poor trunk control², and/or poor foundational support from poorly controlled foot motion¹⁷. The number of athletes that displayed dynamic valgus during fall AOA testing is shocking, where over 92% of all athletes tested displayed dynamic valgus - see Table 1: Athletes displaying dynamic valgus and able to achieve movement standard by competition level.

Comparing Boys vs. Girls

Interestingly we did not find any difference based on gender at the K1 OR K2 levels. This finding is consistent with research from Schmitz et al¹⁸, 2009 who investigated dynamic valgus alignment and functional strength in males and females during maturation and also found no gender differences with athletes prior to adolescence.

Dynamic Valgus and Development

As girls mature their susceptibility to non-contact ACL injuries increase¹⁹. The consensus rationale for this finding is females do not display a “neuromuscular spurt.”²⁰ This means in proportion to their growth and development girls become weaker as they mature⁸. They lose their ability to control their bodies and they become more susceptible to injuries, as supported by the discrepancy in injuries rates between female adolescents (those older than 13 years of age) and young children²¹. In addition there appears to be differences in the ways males and females perform a SLS being disproportionate quadriceps to hamstring activation (females activate their hamstrings significantly less than male counterparts)²², more forward knee movement^{15,16,18}, decreased hip external rotation, and lack of trunk strength¹³.

In the group that we tested at fall AOA testing there we few girls tested at the J or FIS level. We may have seen the typical increased dynamic valgus between males and females if there were more athletes at that age and older. But there were too few athletes to draw a conclusion.

Comparing Dynamic Valgus in High Sport Performers

When we look at high sport performers at the FIS level (AOA Provincial and Development Teams) we see significantly less dynamic valgus. Female athletes on the AOA Provincial team did not display dynamic valgus until they were below a quarter squat depth, where at this depth 33% displayed mild dynamic valgus (no athlete on the AOA displayed severe dynamic valgus). Note over 60% of female athletes tested at Fall Fitness testing were unable to achieve a below quarter parallel squat – see depth analysis of the SLS squat for more information.

Older provincial athletes were even better able to achieve the SLS standard (90% of athletes aged over 16), which is not representative of typical females athletes their age who would display increased dynamic valgus^{8,18}. We believe their leg strength, achieved through dryland training gave them excellent control of their knee.

There appears to be a very strong correlation between high sport performers and the ability to perform a SLS. Athletes that are able to achieve SLS standard, will outperform an athlete unable to achieve the SLS standard. This raises the question, if we improve an athletes’ ability to perform a SLS do we improve their ski performance? From our work the answer is yes.

Assessing the Severity of Dynamic Valgus

The severity of the in table ward knee movement has been classified on the following criteria outlined in Table 2. Noting when dynamic valgus occurs during a SLS is important. Some athletes will stop their SLS before they reach moderate to severe dynamic valgus. This may be because of awareness, apprehension or due to a mobility restriction. Some athletes present with dynamic valgus when they are rising from the bottom position of a SLS. To date no research has investigated the timing of movement dysfunctions during a SLS.

We have developed this classification system based on the work by Noyes et al¹, with the drop jump screen and our work with over 800 athletes tested using the single legged squat test.

We observe specific landmarks on the athletes as they perform the SLS, that has been shown to be reliable and valid with well trained physiotherapists.²³ The landmarks that are used are the hips, knee and lateral malleolus of the ankle. Based on the relative position of the knee relative to the hip separation distance, and ankle position we evaluate knee position.

Observations are further corroborated with video motion analysis using Dart Fish Video Motion Software. Note there are many adjustments that we must make in assessing the severity of dynamic valgus that are beyond the scope of this review. For example, hip shift, internal femoral rotation, toeing out, external tibial rotation, pelvic collapse, pelvic tilting and pelvic rotation. The importance of each of these factors and others are being investigated.

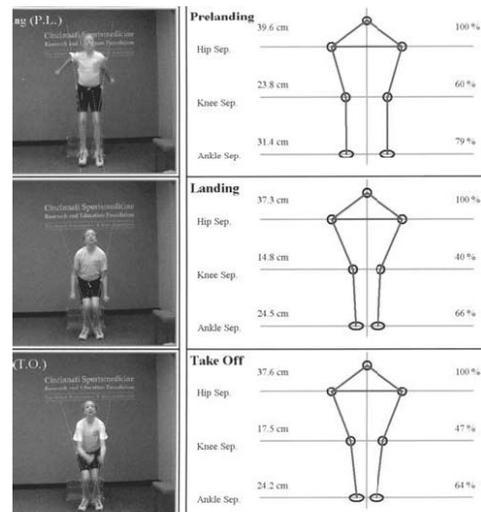


Image Source: Noyes et al, 2005¹

Quantitative Description	
Knee Separation distance relative to Hip Separation	
Mild	< 80%
Moderate	>60% to 79%
Severe	< 60%

Table 2: Dynamic Valgus Classification

As described earlier over 92% of all athletes tested displayed dynamic valgus. When we classified the dynamic valgus based on severity we observe that over 43% of all athletes tested display moderate to severe dynamic valgus. Research indicates the greater the dynamic valgus, the greater the risk for non-contact ACL injuries¹, other knee injuries and low back pain. Athletes displaying moderate to severe dynamic valgus are encouraged to seek guidance from a health care professional guidance or work with a certified strength and conditioning expert on appropriate exercises to reduce and eliminate the dynamic valgus – see appendix for a basic program and guidelines to correct for dynamic valgus. It is advised that these exercises be supervised for correct technique and safety until form is mastered.

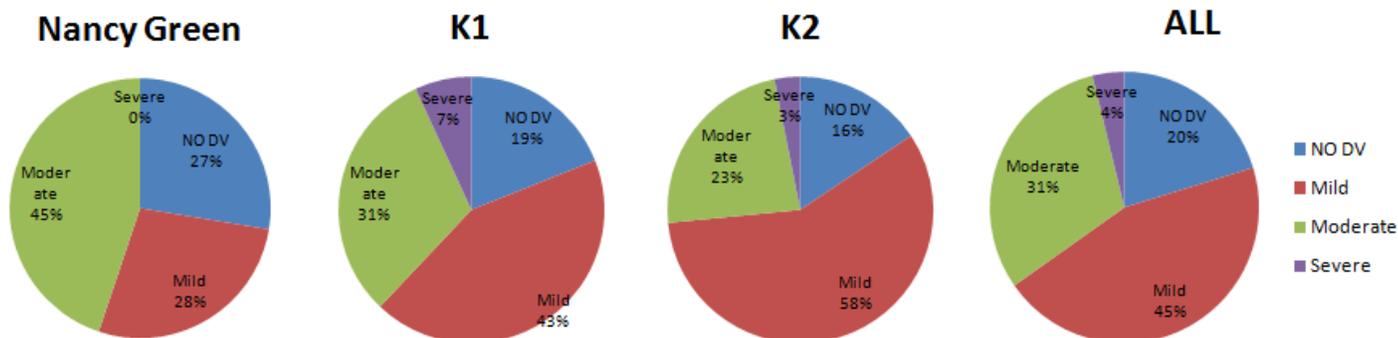


Figure 2: Severity of Right Dynamic Valgus based on competition level. When we examine the right leg we observe a significant discrepancy between males and females where 53.8% vs. 75%, 51.9% vs. 40%, 23.3% vs. 41.7%, demonstrate moderate to severe dynamic valgus for Nancy Green, K1, and K2 athletes respectively. This discrepancy was not present on the left leg. The reason will be further investigated during Spring AOA Fitness testing, based on the addition of more tests and testing equipment.

Single Leg Squat Depth Analysis

The depth an athlete is able to achieve during a single leg squat (SLS) indicates their single leg strength as well as their mobility. Stronger athletes are able to control and descend lower in a SLS than weaker athletes. During testing we indicated the depth they were able to achieve regardless if their form was non-ideal, such as dynamic valgus or loss of neutral spine position.

In future testing we will assess the depth they were able to control before displaying dynamic valgus and the severity of the dynamic valgus and when they lose neutral spine control. The reason for this new method is to increase sensitivity to track changes in movement control. We want athletes to achieve a parallel SLS with control, not a parallel SLS with Results are displayed in Table 3: Depth analysis organized based on competition level and gender.

The depth standard we have chosen is lower than studies within the literature for several important reasons.

LEVEL		DEPTH ANALYSIS		
		Bilateral	RIGHT	LEFT
		% able to achieve movement standard	% able to achieve movement standard	% able to achieve movement standard
Nancy Greene	Group	0.0%	0.0%	3.4%
	Boys	0.0%	0.0%	0.0%
	Girls	0.0%	0.0%	8.3%
K1	Group	6.8%	3.4%	3.4%
	Boys	6.3%	0.0%	0.0%
	Girls	7.4%	7.4%	7.4%
K2	Group	6.3%	12.7%	7.9%
	Boys	5.1%	12.8%	5.1%
	Girls	8.3%	12.5%	12.5%
J-FIS-MS	Group	0.0%	0.0%	0.0%
	Boys	0.0%	0.0%	0.0%
	Girls	0.0%	0.0%	0.0%
ALL	Group	5.1%	6.3%	5.1%
	Boys	4.4%	5.6%	2.2%
	Girls	5.9%	7.4%	8.8%
COMPOSITE K1 / K2	Group	6.6%	8.2%	5.7%
	Boys	5.6%	7.0%	2.8%
	Girls	7.8%	9.8%	9.8%

Table 3: Depth analysis organized based on competition level and gender

First, as our findings indicate many individuals are unable to achieve a parallel single legged squat. To perform research, researchers need to find subjects who are able to achieve the appropriate depth. The sample pools that researchers typically draw from are university students and young athletes without much training. While many individuals are unable to achieve a parallel squat this does not mean it cannot be a standard.

Second, at FITS we see a direct correlation with strength, knee control (frontal plane and saggital plane) and power (SJ, CMJ, Broad Jump, etc.) with an ability to perform a parallel single leg squat. Better athletes are able to achieve a parallel squat. Future research will be directed at investigating the correlation between a single legged squat and sport performance.

Third, this is important is because many of our athletic activities occur on a single leg. Whether we are cutting, sprinting, changing directions we are largely doing this on a single leg. How can we perform these athletic movements if we can't balance on a single leg, squat, and control our knee position – you can't run before you can walk.

Finally, this standard is achievable; as many athletes who we have worked with at FITS achieve a parallel SLS beginning with only a quarter SLS.

Interesting Findings of Depth Analysis

Boys and Girls at the Nancy green level are unable to achieve a parallel squat. Perhaps a standard of a parallel squat is too low for this group.

When we use a standard of below quarter squat the results significantly change - Table 3. As we discussed earlier we have chosen a parallel squat as a standard to reflect the need to increase injury prevention and improve performance. No studies to date have assessed if squatting to a parallel position is linked to decreased injury risk anywhere in the body versus squatting above this standard. That being said, we strongly feel given the demands of the sport, (where control of the knee at parallel position is necessary) that a parallel squat should be the standard.

LEVEL		DEPTH ANALYSIS			
		RIGHT		LEFT	
		% able to achieve movement standard	% able to achieve Below Quarter Standard	% able to achieve movement standard	% able to achieve Below Quarter Standard
Nancy Greene	Group	0.0%	34.5%	3.4%	31.0%
	Boys	0.0%	23.5%	0.0%	29.4%
	Girls	0.0%	50.0%	8.3%	33.3%
K1	Group	3.4%	50.8%	3.4%	45.8%
	Boys	0.0%	43.8%	0.0%	40.6%
	Girls	7.4%	59.3%	7.4%	51.9%
K2	Group	12.7%	63.5%	7.9%	57.1%
	Boys	12.8%	61.5%	5.1%	56.4%
	Girls	12.5%	62.5%	12.5%	58.3%
J-FIS-MS	Group	0.0%	85.7%	0.0%	71.4%
	Boys	0.0%	100.0%	0.0%	100.0%
	Girls	0.0%	80.0%	0.0%	60.0%
ALL	Group	6.3%	54.4%	5.1%	48.7%
	Boys	5.6%	48.9%	2.2%	46.7%
	Girls	7.4%	60.3%	8.8%	51.5%
COMPO SITE K1 / K2	Group	8.2%	57.4%	5.7%	51.6%
	Boys	7.0%	53.5%	2.8%	49.3%
	Girls	9.8%	60.8%	9.8%	54.9%

Table 3: Athletes able to achieve a below quarter SLS vs. parallel SLS

At the K1 level girls displayed better depth than boys both at parallel and below quarter. However at the K2 level there was no difference. The low numbers of athletes at the J level do not allow us to see what happens. It would be very interesting to analyze the depth teenage female athletes and young adult female athletes are able to achieve both absolutely and in comparison to age-matched males. This is especially intriguing given the increased injury rates of females vs. males during and older than adolescence.

Movement Assessment for Drop Jump Screen

The Drop Jump Screen (DJS) examines the athletes' reactive ability and 5-site integrity (complete body control) during a drop from a 35cm box. This test has over 12 years of scientific research, with hundreds of thousands of subjects tested to help predict non-contact ACL injuries.

The same criteria was used for the DJS as the SLS for evaluating the severity of dynamic valgus. We also measured the drop jump height achieved for the purposes of assessing the athletes reactive ability.

The Drop Jump Screen differs significantly from the single legged squat where: a) great forces are being applied to the body during the DJS vs. SLS (>2 x body weight vs body weight respectively); b) during a drop jump athletes are landing with both feet simultaneously (bilateral vs. unilateral); c) athletes are asked to jump as high as possible (high power vs. low force); and d) athletes are asked to jump upon landing (reactive vs. static).

The results showed a significant difference between boys and girls, where girls demonstrated significantly more dynamic valgus both in terms of percentage and severity across all age groups – see Table 4: Drop Jump dynamic valgus analysis. The discrepancy was 54% vs. 86% for the presence of dynamic valgus for boys vs. girls in the composite K1/K2 group and the % of moderate to severe dynamic valgus in this group was 32.8% vs. 47.5% respectively. The severity was even greater at the Nancy Greene level.

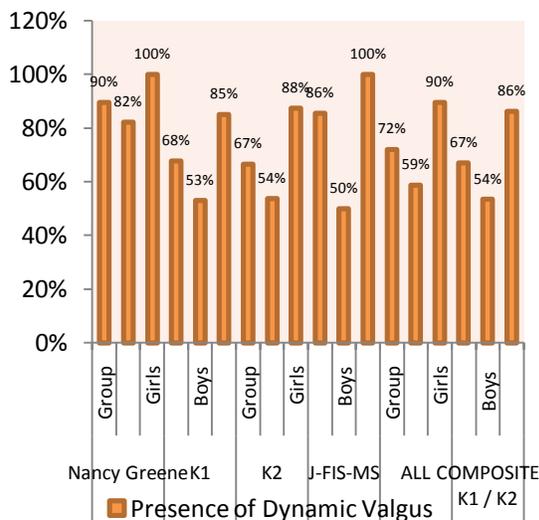
The increased dynamic valgus seen in the girls vs. the boys, as supported by the literature indicates they are at increased risk of injury. Girls do not land with the same land mechanics, in terms of recruitment patterns, ground contact time, and in knee control (dynamic

valgus) as males. This data is very intriguing because when we look at the severity of dynamic valgus and the drop jump height achieved we see that girls and boys are similar up to the K2 level. Girls are able to jump as high, yet display significantly increased dynamic valgus. Male athletes at the K2 level are able to jump 12.2% higher than the girls in response to the drop jump, yet the still have a significantly lower percentage of dynamic valgus compared with females 54% vs. 88%, respectively. It has been appreciated that females have much different power and force absorption recruitment patterns than males. Without question more research is needed to understand the significance of this finding, especially in response to females having increased non-contact ACL rupture risk, as increased with other conditions.

LEVEL		PRESENCE OF DYNAMIC VALGUS				
		% of DV	DVR		DVL	
			% DVR - mod/severe	% mod/severe	% DVR - mod/severe	% mod/severe
Nancy Greene	Group	90%	47.8%	37.9%	44.0%	37.9%
	Boys	82%	30.8%	23.5%	21.4%	17.6%
	Girls	100%	70.0%	58.3%	72.7%	66.7%
K1	Group	68%	35.1%	22.0%	44.1%	25.4%
	Boys	53%	18.8%	9.4%	40.0%	18.8%
	Girls	85%	47.6%	37.0%	47.4%	33.3%
K2	Group	67%	38.9%	22.2%	47.4%	28.6%
	Boys	54%	35.3%	15.4%	36.8%	17.9%
	Girls	88%	42.1%	33.3%	52.4%	45.8%
J-FIS-MS	Group	86%	33.3%	28.6%	33.3%	28.6%
	Boys	50%	0.0%	0.0%	0.0%	0.0%
	Girls	100%	40.0%	40.0%	40.0%	40.0%
ALL	Group	72%	39.2%	25.3%	44.7%	29.1%
	Boys	59%	27.7%	14.4%	32.7%	17.8%
	Girls	90%	49.1%	39.7%	53.6%	44.1%
COMPOSITE K1 / K2	Group	67%	37.0%	22.1%	45.8%	27.0%
	Boys	54%	27.3%	12.7%	38.2%	18.3%
	Girls	86%	45.0%	35.3%	50.0%	39.2%

Table 4: Drop Jump dynamic valgus analysis

Drop Jump Test



Conclusions

Fall testing revealed that over 92% and 67% of athletes tested fail to achieve our movement standards for the SLS and DJS respectively. This is consistent with our work with other provincial sport organizations, and it is the first time movement has been assessed during AOA Fitness testing.

Research indicates that insufficient force production at the hip and trunk, combine with ankle and foot control explain why tested athletes were unable to achieve standards in the SLS and DJS. The prime movement dysfunction displayed was dynamic valgus.

Failing to achieve movement standards for SLS and DJS has been shown in the literature to lead to knee, ligamentous, and low back injuries.

The SLS and DJS are tests performed in a controlled setting. The loads or forces the athlete is exposed to during the tests are at a fraction of the forces that these athletes are exposed with sport participation. For example during skiing athletes can be exposed to forces on a single limb that exceed 3 to 4 times the

forces exposed to during a SLS. Therefore if athletes demonstrate a movement dysfunction during a test they will display a worse dysfunction during sport participation which may lead to an injury.

Injury prevention begins by achieving standards.

Research and our work with athletes show that these standards are achievable. By addressing key movement factors, which are posture, mobility, output and capacity we can achieve movement standards- see Athletic Development guide for information on developing key movement factors (downloadable from <http://www.fitstoronto.com/blog.html>)

Future Initiatives

Our plan at Spring AOA Fitness Testing is to add additional tests and more advanced testing equipment to acquire more information to better help our athletes. We plan on investigating athletes' ground contact times, force production, and their movements in a battery of tests to compliment our current testing protocols.

This initiative will work in collaboration with other provincial sport organizations and other sites around the world to find more answers on how to best develop movement and to further understand risk factors for common sport medicine injuries.

There are many answers to uncover, en route to making skiing safer and to improve performance. The key to moving forward is how we move.

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