The Prevalence and Efficacy of Cross-training in a Professional Ballet Environment: A Literature Review

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The prevalence and efficacy of cross-training in a professional ballet environment: a literature review

By

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Abstract

Fear of ruining the aesthetic integrity of the ideal “ballet body” once barred many dancers from cross-training for endurance and strength, but evidence suggests that these concerns are largely unsubstantiated, and several major dance companies have started integrating supplementary training into their class and rehearsal regimens. Ballet-specific risk factors, busy performance schedules, and the disparity between class and performance demands all limit the extent to which fitness training can be incorporated into professional environments. In addition, the applicability of objective technique analysis in subjective sports and a lack of reliable research within the population of interest have constrained the development of coordinated systems of care amongst medical and artistic professionals. However, other sports set the standard for the future of a field which is progressing in the hands of pioneering experts across the globe.

In this thesis, I will use a detailed literature review to outline the anticipated effects of a multifaceted cross-training program on the strength and endurance of professional ballet dancers and make suggestions for further research as it relates to the prevention of overuse injuries, the unique demands of ballet, and the periodization of training. These recommendations will be based upon the standards set by other sports as well as the opinions of current professionals who work within the confines of an emerging field.
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Introduction

In the early 1400s, ballet was conceptualized as a form of theatrical entertainment for Italian and French nobility. What is now celebrated as a fusion of intense athleticism and art was lauded as a storytelling medium through which men in elaborate costumes reenacted borrowed tales of ancient mythology as guests of the rich. It wasn’t until the middle of the 17th century, when opera houses and theatres gained prominence in Europe, that ballet expanded beyond the confines of imperial ballrooms and challenged both the physical and thematic expectations from which it began. Along with the advent of pointe shoes and increasing visibility of female dancers during social upheavals of the French Revolution, this shift from palaces to the stage redefined antiquated conceptions of ballet which ultimately grew into a more physical form of expression. Because public theatres were not as intimate as the royal courts of King Louis XIV, dancers adapted their choreography to be more well received by larger audiences. They jumped higher, turned out through wider ranges of motion, performed more consecutive turns, and attempted more demanding partner lifts. This increase in the physicality of performance necessitated a greater emphasis on physical fitness overall and ultimately catalyzed the birth of dance medicine.

A far cry from its earliest days, modern dance science is a field that comprises talented medical and artistic professionals who collaborate to provide quality health services aimed specifically at dancers. It is a relatively young and niche profession, only receiving public recognition in 1990 when its pioneering agency, the International Association for Dance Medicine and Science (IADMS), was founded. Since then, IADMS has grown to include more than 900 members, and its influence has spread to nearly forty countries. Committed to “enhancing the health, well-being, training, and performance of dancers by cultivating medical, scientific, and educational excellence,” the group serves as a precedent for future agencies dedicated to understanding and treating the unique injury risk factors associated with dance.

For as long as medical professionals have worked with ballet dancers, they have recognized the need for tailored research. Though ballet has traditionally received far less attention than more common methods of exercise, it is gaining more traction in sports physiotherapy and related fields. While regularly scheduled classes and rehearsals were once considered sufficient enough to promote optimal performance, recent data have warranted a closer look at the credibility of such assumptions, suggesting that cross-training plays an integral role in both injury prevention and performance enhancement. The cost of time off due to injury in terms of both financial and human capital, disparity between the physicality of class and performance, and distinct technical standards associated with ballet justify the need for specialized training. In this thesis, I will use a detailed literature review to outline the anticipated effects of a multifaceted cross-training program on the strength and endurance of professional ballet dancers and make suggestions for further research as it relates to the prevention of overuse injuries, the unique demands of ballet, and the periodization of training. These recommendations will be based upon the standards set by other sports as well as the opinions of current professionals who work within the confines of an emerging field.

Aesthetics

Nico Kolokythas, ASCC, PhD, acting performance enhancement coach for the Elmhurst Ballet School and strength consultant for the associated Birmingham Royal Ballet, is a current leader in
dance science research. He encapsulated the need for supplementary training in a personal interview when he emphasized that dancers must focus on conditioning their bodies for what they do rather than using what they do to condition their bodies. In doing so, Dr. Kolokythas alluded to a pervasive misconception in the dance community that resistance training induces muscular hypertrophy and ruins the aesthetic integrity of the “ideal ballet body”. The desire to maintain a lean physique at the expense of gaining strength is one consequence of the subjective nature of ballet and one of many factors that contribute to the acceptance- or lack thereof- of cross-training today. However, a growing emphasis on functionality has helped curtail this fear. According to lead physiotherapist of the Australian Ballet, Susan Mayes, AM, PT, PhD, the marketing departments of major companies like hers are beginning to promote strong, athletic body types, and the Birmingham Royal Ballet, Australian Ballet, and Alvin Ailey company are among those who are beginning to incorporate cross-training into their regimens.

While these changes are necessary and welcomed, the tradeoff between appearance and functionality might not be as drastic as we think. Twenty-four professional and vocational contemporary dancers participated in a 6-week exercise intervention study in which the experimental group completed two 1-hour circuit training sessions per week. The circuit consisted of a succession of 9-12 workouts performed for 15-45 seconds with 0-30 seconds of rest in between. Exercises included “jumps with feet in parallel position (using a jumping rope), press-ups, bicep curls, triceps extension (with free weights of 0.5 kg each), single leg squat, squats-jumps, heel-rises in dance first position, deep squats in dance second position, chest press exercises (with free weights of 0.5 kg each), and planks” in addition to whole-body vibration training. While it may come as no surprise that dancers in the experimental group gained lower body muscular power, upper body muscular endurance, aerobic fitness, and aesthetic competence, it was particularly interesting to note that dancers in the control group actually reported lower “aesthetic competency” scores than those who engaged in cross-training. Though admittedly preliminary and lacking in scientific validation, these results tentatively suggest that supplementary training protects aesthetics more than it threatens them. While this study did not address my specific population of interest, its implications can still encourage the implementation of cross-training and guide exercise intervention design in terms of both the specific movements used and the structure of the workout as a whole.

In another study conducted in 2009, Angioi et al. compared the results of physical fitness tests with aesthetic competence assessments commonly cited by contemporary dance companies as factors in hiring decisions. Seven of the most common auditioning criteria for companies in the United States, United Kingdom, and Australia were evaluated on 10-digit Likert scales for a total aesthetic competence score of 70. Two dance teachers were recruited to judge six professional contemporary dancers who had 20 minutes to learn and five minutes to practice a 60-second piece of choreography. Performances were videotaped and copied so that both judges watched all six dancers three separate times for a total of 18 trials. Showing blinded copies of the same videos ensured intra-test-retest reliability while comparing the scores of both judges addressed issues of inter-rater reliability. After the precedent was set, 17 dancers were recruited for the association study in which they were graded on several fitness parameters defined by the British Association for Sport and Exercise Sciences and the American College of Sport Medicine. Anthropometric measures like height and total body mass were measured along with flexibility, muscular power, muscular endurance, and aerobic capacity through a mix of dance-specific (développé à la seconde for active range of motion versus flexibility in the hip) and generalized (maximum push-up count and plank hold for muscular endurance) fitness tests.
Then, each dancer in the experimental group completed an aesthetic competence test similar to the one administered to the six initial dancers. All 17 participants learned a 90-second piece of choreography that was judged by one professional. Statistical analysis revealed that the aesthetic competence test developed in the initial phase of the study is reliable and that upper body muscular endurance and lower body muscular power (as determined by the push-up test and jump ability test respectively) were both predictive of aesthetic competence. While Angioi et al. admit that, “contemporary dance is characterized by a greater variety of technical demands imposed by choreographers during performance” than classical ballet, the study still sets a precedent for the way we might rate performance and test performance enhancement in the future.

Risk factors

Studies that exemplify the way in which we might make subjective measures of dance more quantifiable are constrained by the complex nature of ballet. Dr. Adrian Lees, professor of sport biomechanics at Józef Piłsudski University of Physical Education in Warsaw, warns that performance quality is multifactorial and should not be attributed solely to technique, regardless of the sport. Campbell et al. address this idea specifically as it relates to dance when they cite hypermobility, degree of turnout, neuromuscular dysfunction, weakness of core and lower extremity muscles, range of motion in the lower extremities, fatigue, and overuse as intrinsic modifiable injury risk factors unique to ballet dancers. General joint hypermobility (GJH) can be hereditary or acquired and is seen in 66% of dancers as opposed to 29% of non-dancers. GJH leads to unequal force distribution and “laxity of structures” within the joints that induces chronic ankle instability, anterior cruciate ligament (ACL) injuries, tendinopathies, general joint degeneration, and hip instability. Defined as the degree of external rotation in the hips, knees, and ankles, turnout is an integral component of ballet. Dancers are more susceptible to lower extremity injuries when they overtax their natural, anatomical turnout with repetitive stretching and stress. Campbell et al. refer back to the aesthetic demands of ballet, admitting that, “while the ability to have extensive external rotation is an essential component to the aesthetics of ballet dance, forcing the range of this motion stretches the capsular structures that can lead to painful injuries within the hip”. Excessive turnout induces pelvis tilting (a postural fault that Dr. Mayes has specifically addressed at the Australian Ballet, though she actually endorses a slight anterior tilt). In addition, dancers often attempt to overcome turnout limitations by contorting the angles in their knees, heels, feet, and spine. Dancers who compensate in these ways are 9% more likely to get injured.

When it comes to fatigue, compensation also alters neuromuscular functioning. Deficits in proprioception, balance, strength, and overall movement affect landing and twisting mechanics and induce injuries while jumping and turning. Neuromuscular dysfunction is exacerbated by weakness, especially in the lower extremity and core, and often plays a role in range of motion discrepancies. Finally, the “rigor, volume, and demands of practice and performance” for dancers leads to fatigue and overuse. In fact, over the course of an average 9-hour workday, 90% of female ballet dancers received less than 60 minutes of rest (defined as exertion below 1.5 metabolic equivalents (METS)), and one third of them received less than 20 consecutive minutes. Most professionals have technique classes and several hours of rehearsals or performances each day, “rendering them more liable to suffer from injuries and even permanent disabilities than most sport competitors.”
Regardless of intensity, professionals work at a high volume, often dancing between six and eight hours a day in rehearsal periods and up to ten hours a day in performance periods. Typical performance schedules comprise eight performances a week for four to eight weeks in addition to daily classes and rehearsals. Dancers in a 2005 injury intervention study performed 145 times in 15 different shows in year one, 143 times in 18 different shows in year two, and 142 times in 20 different shows in year three. While the number of annual performances plays an obvious role in short-term fatigue, Vice President of IADMS, Cofounder and Medical Director of SeaPAM Performing Arts Monthly Clinic, and Consulting Physician with Pacific Northwest Ballet (PNB), orthopedic surgeon, Nancy Kadel, MD, pointed out the long-term impact of preparing for and performing multiple different shows throughout the season in a personal interview. For example, while a company is performing the Nutcracker in the winter, they are also rehearsing for a modern piece that debuts in the spring. The disparate demands of two different styles of dance and the increasing complexity of choreography as a whole both increase the likelihood of injury.

Much like neuromuscular dysfunction, this kind of fatigue interferes with proper landing mechanics which explains the disproportionate number of lower extremity injuries that occur later in the day or later in the season. Regardless of when they occur, research has shown that 75% of ballet injuries are related to overuse compared to just 21.7% of injuries in other elite sports, but Allen et al. specifically cite injuries occurring at the end of rehearsals to justify strength and endurance conditioning. Because of the influence of fatigue on injury incidence, a focus on physical fitness will only be beneficial if it can be implemented within a periodized framework.

**Periodization**

Athletic periodization is the segmentation of yearly training schedules into several smaller, more easily managed phases which can be categorized as preparatory, competitive, or off-season. The methodology has played an important role in the highest level of sport and can be traced back to the ancient Greek Olympians. It was conceptualized by two Soviet physicians, Mateev and Ozolin, who defined it as a means of “reach[ing] a high level of performance and ‘athletic shape’ at a given time”, so that the athlete peaks during competition or performance. Periodization attempts to coordinate multiple facets of training including adaptation, skill development, and climate so as to promote peak performance when it matters most. The preparatory phase should consist of a training program that maximizes neuromuscular and cardiorespiratory adaptation, strength, speed, endurance, and technical skill. In the first third of the phase, non-specific training is emphasized. In the latter two-thirds of the phase, sport-specific training is implemented. Because athletes are not faced with the stress of competition, this phase of intense work provides the foundation for competitive peaks when fatigue is more of a risk factor. Resistance against fatigue protects against injury and promotes psychological health, as physical exhaustion “affects [an athlete’s] visualization, concentration capabilities, focusing, and motivation”. Intensity of training is directly correlated with stress, so longer, less demanding pre-competition periods are more effective than more demanding ones.

The first periodization model was based upon the cyclic timeline of the Olympic Games and allowed for one competition phase, but modern renditions are more nuanced and apply the same concepts to more complex competition schedules. Track and field athletes employ a bi-cyclic, or double-peaking, plan to accommodate both indoor and outdoor seasons. Swimmers
follow similar patterns for short and long course training, while wrestlers, boxers, and martial artists often use tri-cyclic plans. It is harder to periodize for sports that require multiple peaks each year\textsuperscript{11}, which is often the case with individual sports like ballet. Bompa suggests that overtraining and associated overuse injuries can be avoided by prioritizing the planned peaks that correlate with championships. At the very least, dancers can avoid challenging workouts directly following taxing performances, relax for at least two weeks after performance phases, and structure micro-cycles with principles of step loading methodology which suggests a chronological progression of low, medium, high, and low intensity training sessions over the course of the week\textsuperscript{11}.

The degree to which these recommendations can be implemented in a professional ballet environment is constrained by the performance schedules of companies. But periodization should be used because of these risk factors, not in spite of them. Wyon notes that it is a necessary consideration for dancers in light of the increasing complexity of both choreography and performance schedules and that it promotes physiological, psychological, and biomechanical health in addition to skill\textsuperscript{9}. Because of the busy schedules of most professional ballet dancers, Wyon specifically suggests the method of block periodization, which was proposed by Yuri Verkhoshansky, a well-known sports scientist whose work has been applied to Olympic training cycles. In the first “block”, athletes work at a high volume, low work power ratio to improve motor potential and functional specialization. In “blocks” B and C, athletes increase their work power at the expense of training volume\textsuperscript{12} (Appendix A). Nonspecific periodization models have been validated through several studies which determined that periodized athletes performed better than those who did not coordinate their training and competition schedules. Mateev and Ozolin suggest that a 3%-6% increase in training load followed by a period of tapering right before performance or competition is necessary to induce “supercompensation of the energy stores, neural and cellular recovery of the musculoskeletal systems, and an increase in strength and power”\textsuperscript{9}.

In an effort to accommodate these recommendations, Wyon suggests that if performances start on Saturday, Wednesday would be the last day of normal rehearsals with high intensity and moderate volume. On Thursday, Friday, and Saturday, intensity would increase while volume significantly decreased. Thursday and Friday mornings would consist of a short technique class, dress rehearsal, and film review with short rehearsals of any specific problem areas determined through video assessment. Imagery is a powerful tool to use, especially when closer to performance, as it increases performance quality without an associated increase in training quantity. In general, supplemental training can be justified up until the last two weeks before a performance in which it should decline in volume, before stopping completely one week out so as to compensate for increased rehearsal time. As the volume of cross-training decreases, intensity can either remain the same or increase. Tapering methods similar to those proposed by Wyon benefited dancers’ physiological performance and decreased mood disturbances in one dance company by 50\%\textsuperscript{9}, though the potential for tapering to induce boredom and a fear of losing one’s place within the company are two potential externalities that deserve further investigation.

While periodization should factor into weekly scheduling, it can also be applied to performance days which should be treated as microcosms of the performance season as a whole. For a show that starts at 8:00 pm, an hour-long warm-up class from 10:00 to 11:00 am would be followed by rehearsals from 11:30 to 3:00 pm, a meal at 4:00 or 5:00 pm, and a 20-minute warm-up just prior to performance\textsuperscript{9}.
Wyon is careful to warn that while Verkhoshansky’s model promotes aerobic, anaerobic, strength, power, and flexibility gains simultaneously, companies should specifically emphasize those factors which are most relevant to the performance in question. He also stipulates that dancer fitness and company rank should be considered when formulating a periodization schedule for individual dancers that fits within the general plan of the company. These unique factors, which set dance apart from other sports that take advantage of periodization techniques, will also serve as barriers to the proper and effective application of such principles in a real-world context. In fact, Wyon admits that his advice is based off of experience and theory as “only a few dance companies have implemented this methodology into their planning and scheduling,” providing yet another reason to heed the advice of Dr. Mayes, Dr. Kolokythas, and Dr. Kadel who stress the need for more randomized controlled trials within professional environments.

**Energy expenditure**

While the evidence to support specific recommendations is lacking, it is clear that dancers rarely maximize their physiological exertion during performances— in part because it is noncompetitive, and exercise intensity is determined by choreographers instead of the athletes themselves. In addition, many studies have suggested that technique classes, rehearsals, and performances do not stimulate cardiovascular endurance in a significant way, comparing the aerobic fitness of dancers to that of non-endurance athletes. In fact, research suggests that dancers more closely resemble athletes in “power-based sports where there is a predominant anaerobic component.” Some data have alluded to a thickening of the left ventricular wall of the heart in dancers compared to a control group, but there was no associated increase in ventricular volume that would be indicative of increased aerobic fitness. Authors suggest that this is a product of the dual isometric-isotonic demands of ballet. This sentiment is shared by Twitchett, Koutedakis, and Wyon who compared the physical demands of ballet class, ballet performance, and other athletic events in order to argue that dancers are actually less physically fit than most other athletes, relying on skill instead of strength to carry them through intense training and performance schedules. Wyon and Moita et al. both concur, warning that professional dancers often exhibit fitness levels comparable to sedentary adults of similar ages. "The repetitive nature of dance movement patterns in classes and rehearsals without adequate rest in between leads to fatigue which promotes a lack of proper alignment as skill is undermined." This issue is exacerbated by intense choreography and performance schedules that are only supplemented with more dance. Like rhythmic gymnastics, dance views physical strength as a means to the successful demonstration of sophisticated skill patterns rather than as an end within itself. Both classical ballet and contemporary dance use rehearsals to prepare for performance, despite the disparity between the physical stresses of rehearsal and those of performance which stimulate fast glycolytic and aerobic systems to a much greater degree. This disparity is demonstrated by proven increases in aerobic fitness during performance seasons as compared to preparatory periods.

Cohen et al. recorded the VO2 max of fifteen American Ballet Theatre dancers (seven men and eight women between the ages of 20 and 30) during treadmill running and a typical 1-hour ballet class consisting of 28 minutes of barre exercises and 32 minutes of center floor exercises. Measured in beats/min (bpm), heart rate (HR) data from eight of the dancers who underwent maximal treadmill running tests revealed that the average VO2 max reached was 48.2 ml/kg/min.
for men and 43.7 ml/kg/min for women. HR data from ten of the dancers who took the standard ballet class showed that the average VO2 reached during barre was only 38% of VO2 max as measured by the treadmill test (18.5 ml/kg/min for men and 16.5 ml/kg/min for women). Not surprisingly, VO2 averages for center exercises were higher in both genders (26.3 ml/kg/min for men and 20.1 ml/kg/min for women). However, these values were only 55% and 46% of max VO2 for men and women respectively. The training sensitive zone is the HR range which induces increased aerobic fitness and is commonly considered to be 70% of max HR within the wellness community. Cohen et al.’s data indicate that dancers’ HR did not meet or exceed this benchmark for any significant period of time during barre. While men reached a peak HR of 178 bpm (92% of HR max) and women peaked at 158 bpm (85% of HR max), these elevated states were only maintained for brief periods of time. Thus, the commonly cited caveat that longer exercise duration might compensate for lower maximal HR does not apply.

Barre is comprised of consecutive 4 to 5-minute periods of low-intensity exercise that stimulate the aerobic system with average HR between 117 and 134 bpm, while center is comprised of alternating periods of intense work (10-40 seconds) and rest (2-5 minutes) which stimulate the anaerobic system to a greater degree in between periods of complete recovery. Performances mirror the intensity of center with the duration of barre (1-4 minutes), recruiting both the glycolytic (aerobic) and glycogenolytic (anaerobic) respiratory systems. While both pathways are normally in use, the intensity of work and muscular demand for ATP determines the ratio of energy production. Two minutes of maximal exercise is generally considered the point at which both pathways contribute 50% of the energy. Beyond that, there is a direct relationship between the duration of exercise and the contribution of the aerobic pathway. Even so, increased aerobic capacity can enhance anaerobic functionality by maximizing rest period recovery. In fact, Wyon suggests that dancers should develop their fast twitch muscle fibers (typically recruited during high-intensity training) and aerobic capacity before rehearsal periods in which they can allow performance preparation to induce cardiovascular gains organically. This training structure demands the implementation of periodization within a three-tier process in which “the first stage develops an aerobic foundation, the second stage facilitates maximal aerobic power, and the third stage develops the fast-glycolytic system”.

Wyon emphasizes the aerobic foundation period for its promotion of overall conditioning and ensures that benefits can be gained regardless of whether the training is dance-specific or more generalized as long as intensity remains within 60%-85% of VO2 max and 70%-90% of HR max throughout 20-40-minute sessions. In the second phase, the aerobic power phase, Wyon stresses the importance of raising a dancer’s VO2 max threshold as a preventative measure against fatigue-related injury. In this stage, dancers should work within a 1:1 exercise to rest ratio, with each interval lasting between 3-6 minutes and operating within 90%-95% of either VO2 max or HR max. It should be noted that rest periods are periods of low intensity work rather than the cessation of exercise. In the final stage of Wyon’s model, dancers should work at supramaximal intensity within an exercise to rest ratio between 1:3 and 1:5, each interval lasting 15-30 seconds.

As Wyon has noted; however, a typical dance class or rehearsal does not elicit sufficient stimulation for significant physical adaptations, particularly in terms of muscular strength, or aerobic and anaerobic endurance that become necessary during performances. If the first priority of professional dance companies is to adequately prepare every dancer for opening night and maintain that level of readiness throughout the season, diversified training programs are an
essential component of this bottom line. Angioi et al. demonstrated that dancers who participated in two hours of supplementary training each week did not see a decline in skill or physiological measures as compared to the control group who participated in two hours of technique class instead. In fact, the experimental group saw better outcomes than those who trained exclusively with dance. In making his recommendations, Wyon cites the busy schedules of professional dancers and warns of the potential for overtraining and increased incidence of the very overuse injuries which he is trying to prevent. Thus, he posits that professionals substitute “one or two dance classes a week with physical conditioning as this would have a beneficial effect on the dancers’ underlying physical fitness without interfering or causing a deterioration of skill.” He claims that there would be no loss in skill if dancers maintained a schedule of three classes per week in addition to rehearsal and performance but admits to a lack of evidence to support this claim. In addition, Wyon concedes that three or four weekly sessions might be reduced to one or two weekly sessions when rehearsals or performance are particularly taxing, but gives no distinction between regular and intense rehearsal from which the line might be drawn.

Twitchett et al. agree that substituting two or three weekly technique classes with physical conditioning would benefit professionals’ fitness without compromising skill. In order to maximize aerobic and strength gains within the strict limitations imposed by professional ballet schedules, both Rodrigues-Krause et al. and Twitchett et al. recommend high-intensity interval training (HIIT). HIIT closely resembles modern choreography and has the ability to enhance muscle power reserve, muscular endurance, and cardiorespiratory endurance for explosive jumps, allegros, and grand adage respectively. Because HIIT mirrors the demands of modern choreography in which periods of high intensity activity are interspersed with shorter rest periods, training in short bursts of acute activity enhances oxidative metabolic pathways and delays the onset of fatigue. Rodrigues-Krause et al. specifically suggest that a HIIT program “with exercise-rest ratio 1:1, exercise time 3 to 6 min, [at] 90 to 95% of VO2 max, RPE 16 to 17, and active recovery at low aerobic intensity” might be used to reconcile the difference between class and performance.

Company rank

Although researchers rationalize the need for supplementary training by contrasting the disparity between rehearsal and performance as well as the physical deficits of dancers to those of other elite athletes, even dancers of different ranks within the same company exhibit obvious differences in physical fitness. Unlike most other team sport athletes who demonstrate similar cardiovascular endurance to their teammates regardless of playing position; principals, soloists, first artists, and corps dancers display definitive differences in their cardiovascular markers. Forty-nine dancers in a professional touring ballet company participated in a study that demonstrated these disparities. In order to test peak VO2, dancers wore a telemetric gas analyzer while running on a treadmill which increased in speed by 0.5 km/hour every 30 seconds. Each participant started at a predetermined speed (typically between 6 and 8 km/hour) at which their HR reached 120 bpm. Each participant stopped when their oxygen consumption plateaued or when their HR reached a standardized, age-related value. Principal dancers had higher VO2 max values (49.84 ± 4.03 ml/kg/min for men; 47.03 ± 1.65 ml/kg/min for women) than their corps counterparts (49.79 ± 3.59 ml/kg/min for men; 44.57 ±4.19 ml/kg/min for women) when sorted by gender. However, corps dancers had higher VO2 max values than both soloists (47.15 ± 4.15 ml/kg/min for men; 40.50 ± 6.72 ml/kg/min for women) and first artists (46.39 ± 4.97 ml/kg/min for men; 40.13 ± 5.87 ml/kg/min for women).
for men; 39.04 ±4.72 ml/kg/min for women). As a means of measuring jump height, participants jumped straight up from a first position plié with both arms at their sides. They repeated the exercise three times from both legs as well as from the left leg only and right leg only and recorded the highest of three jumps for each scenario. As with the cardiovascular data, principal and corps dancers could be grouped by their average jump heights which were noticeably different from those recorded by soloists and first artists. However, principals (50.5 ± 3.79 cm for men; 33.0 ± 1.41 cm for women) and corps (50.8 ± 7.94 cm for men; 37.3 ± 5.63 cm for women) showed lower values than soloists (55.3 ± 4.99 cm for men; 39.2 ± 5.74 cm for women) and first artists (56.0 ± 9.76 cm for men; 39.0 ± 2.82 cm for women). Because self-reported supplemental training was not predictive of either factor, Wyon et al. concluded that VO2 max and vertical jump height are more closely associated with the everyday demands of company rank than with cross training. For example, corps dancers performed more regularly than principals, soloists, and first artists and thus had the highest workload. This was reflected in their increased VO2 max.

Though principals have a lower workload than any of the other three company ranks, their increased VO2 max values are not as contradictory as one might think. Wyon et al. cite the results of another analysis when they suggest that the higher intensity of most principal performances makes up for their lower workload when it comes to cardiovascular training. This finding specifically supports the use of HIIT as a means of increasing aerobic capacity when training volume is constrained by performance schedules, but Wyon et al. note that their study verified both uninterrupted low to moderate intensity exercise (reminiscent of corps choreography) and discontinuous high-intensity exercise (similar to principal choreography) as methods of enhancing aerobic power. In a personal interview, Dr. Mayes promoted the integration of individual training programs for each dancer in her company, suggesting that different modalities are not mutually exclusive.

Although Wyon et al. stipulate that VO2 max and vertical jump height are independent of self-reported supplemental training, both the direct relationship between muscle circumference and leg strength and the correlation between leg strength and jump height suggest otherwise. In fact, Wyon et al. conclude their findings by admitting that supplementary training did not necessarily benefit dancer fitness in this specific study but that “these data can help guide strength and conditioning intervention strategies that need to take into account the nuances of the different seniority levels within a dance company.”

Studies have suggested that VO2 is a better measure of dance exercise intensity than HR, but Rodrigues-Kraus et al. warn that inconsistencies between testing methods and movement patterns typically executed by dancers might lead to an underestimation of critical metrics, and lower than expected aerobic capacity might be more indicative of unfamiliar testing modalities than of deficits in fitness. Maximum effort exercise tests like those performed on treadmills or workout bicycles cause “dancers to be biomechanically inefficient, since their particular physical characteristics [such as extreme turn out] may produce pain and discomfort while working to volitional exhaustion, which they are not used to.” While a focus on technical development over progressions in volume and intensity means that dancers typically have lower aerobic capacity and strength than other athletes, “it is widely acknowledged that testing anyone’s cardiorespiratory fitness on a modality with which they are unfamiliar will always produce lower VO2 peak/ VO2 max values.” Twitchett and others have proposed an incremental VO2 max test more appropriate for dancers in which participants perform five stages of sixteen 4-minute tempo dance routines. The first stage would only induce VO2 values similar to those reached in class (22 to 25 ml·kg·1·min·1; 50% of VO2
max). Progressions would work through rehearsal and performance intensity (38 to 43 ml·kg\(^{-1} \cdot \text{min}^{-1}\); 85% of VO2 max) and perhaps even further\(^2\).

Perhaps the underestimation of data as a result of problematic measurement techniques suggests that testing protocols ought to be as dance-specific as the interventions they vindicate. Even within dance-specific tests; however, the quality of movement can have a spurious effect on data. In a study done by Tiemens et al., dancers performed the Dance-Specific Aerobic Fitness Test (DAFT) twice, once “as if they were performing [and once with specific instructions to] reduce the quality of movement”\(^{18}\). Dancers wore a Polar HR monitor that measured heart rate at each of five DAFT stages as well as one and two minutes after completion. Tiemens et al. found that both perceived and measured exertion were higher during the performance quality trial, suggesting that even dance-specific metrics can deliver disparate results if not implemented carefully. Regardless of the nature of the test, specific instructions are integral to valid findings, lest a lack of effort be perceived as good aerobic fitness. Indeed, while data suggest that muscular strength and power correlate directly with jump ability and overall performance, the credibility of these findings is limited by the aesthetic assessment tools used without prior validity and reliability valuation\(^4\). An aesthetic competence test used by Angioi et al. consisted of 90 seconds of contemporary choreography performed and filmed before and after an exercise intervention. A dance teacher graded each performance on seven criteria established by the authors with no previous knowledge of control versus experimental group or pre versus post-intervention group\(^4\). While the findings of the study would be an interesting look at the effect of cross-training on performance enhancement, it would first be critical to assess the parameters by which Angioi et al. determined their intervention to be “dance-specific” or their findings to be valid.

**Technique analysis**

Dr. Adrian Lees recognizes that studies like these might stake their misleading findings on skill over fitness when he addresses the unique challenges of analyzing technique in subjective sports\(^6\). When it first showed up in the scientific literature nearly 50 years ago, technique analysis was a qualitative analysis tool for coaches who had little means of objective measurement. Technological advances now permit the collection of kinematic and temporal data with more quantitative methods, though these have been more well received in clinical settings than in applied settings where “the focus is still on the whole movement”\(^6\). Lees identifies several different means of observation when it comes to measuring technical success. Temporal analysis breaks skills down into their sequential phases and includes the concept of rhythm, an integral component of dance technique. However, both rhythm and dance in general “receive little attention in most sports biomechanics texts”\(^6\). But, technique analysis is poorly applied in many other sports settings as well. Visual templates of experts performing a specific skill have been used to demonstrate specific movements, but this approach places too much emphasis on technical skill which is not necessarily indicative of correct technique. Several researchers have suggested that biomechanical principles of movement should guide technique analysis, but “there is little detailed agreement as to how [the principles] should be categorized […] and no agreement about what each principle is fundamentally based on”\(^6\), which has complicated any practical applications. Proposed systematic models fall apart when they identify performance factors instead of technique, but statistical models may have more merit, as they allow for the measurement and consideration of joint angle, velocity, and other quantifiable kinematic
variables. This kind of analysis sets benchmarks which can be used to measure improvements over time. For example, golfers use hip-shoulder separation and soccer players use pelvic rotation to assess form. Overall, although Lees admits that these variables were selected based upon general principles of movement which have not necessarily been identified as valid inclusion criteria, they serve as an example of what future biomechanical techniques might look like. He also suggests that artificial neural networks and inter/intra-limb coordination might shape the future of quantitative biomechanical analysis.

Koutedakis et al. attempted to answer the question of whether the subjective nature of dance can be quantified so as to measure performance enhancement comparatively. They employed a test in which dancers performed parallel sideways jumps, landing on one leg, travelling away from and back towards the center of two concentric circles drawn on the floor spaced 60 and 70 cm and 55 and 65 cm apart for boys and girls respectively. The dancers were instructed to continue jumping in alternate directions until they felt their technique begin to decline with fatigue. Dancers were scored based off of both the number of jump repetitions as well as “artistic competence […] which took into consideration posture and alignment, use and articulation of upper body and arms, lower body and feet, total body coordination, and presentation of movement”. In addition, spatial accuracy was factored into the scores. If dancers returned to the inner concentric circle, one point was deducted, and if they returned to the outer concentric circle, two points were deducted. Of course, the concept of artistic competence itself is controversial in its interpretations, and the reliance on self-perception of technical decline is problematic.

These deficiencies are also exemplified by the criteria with which ballet teachers determine pointe-readiness. Length of dance training and ankle plantar flexion range of motion have long been considered the only major considerations other than a chronological age of at least 12 years. However, Richardson et al. hypothesized that dynamic motion tests are a better means of assessment. To evaluate this theory, Richardson et al. performed nine different tests on thirty-seven New York-based pre-pointe ballet students from 9-17 years old and compared results with subjective teacher ratings of perceived pointe-readiness. The “Pencil Test” and Double-Leg Lower Test measured plantar flexion and core stability. A modified “Romberg” test measured the ability to balance in a flat-footed passé-relevé foot for more than 30 seconds with both eyes closed and exemplified how we might adapt general functional exams to be more dance-specific. Only three tests showed clear association with subjective teacher ratings, and Richardson et al. suggest that these should be implemented in the determination of pointe-readiness. The “Topple” Test, which assessed form during single pirouettes en dehors, was also dance-specific. The “Airplane” Test assessed neuromuscular control of the lower extremity and ability to plié without pelvic drop, hip adduction, hip internal rotation, knee valgus, or foot pronation. The Single-Leg Sauté Test was another dance-specific measure of dynamic trunk control and lower extremity alignment during consecutive single-leg jumps. Interestingly, the Single-Leg Heel Rise Test (which resembles that used by Dr. Mayes to justify dancers performing at least 25 single leg heel raises every day) was not closely associated with subjective teacher appraisal. Richardson et al. claim that “tests that require dance specific postures and tasks allow the examiner to test integration of strength, control and alignment that express technical accuracy specific to the classical dance artform”. This conclusion suggests that both generalized and dance-specific tests might be useful in measuring dancer fitness which only strengthens the argument for the development of valid and reliable metrics.
Sport specificity

While the guidelines used to assess the efficacy of exercise interventions should be somewhat dance-specific, the consensus among most professionals is that the exercises themselves are most effective when they include both balletic and general movements. When asked about whether dancers should train muscles they will use during performance (such as hip adductors for turn out) or muscles that are not typically activated in ballet technique, Dr. Kolokythas answered that both are necessary. Because most dancers decide what they want to do at a very young age and dedicate themselves to a single discipline at the expense of all else, dancers do not get a sufficient amount of muscular adaptation. Specialization makes dancers “ballet strong” but risks the development of major imbalances in hip internal and external rotation and other binary systems which can undermine technique as the negative effects accumulate in broader movements. Training opposite muscle groups from a young age can protect against such imbalances and promote accurate muscle recruitment. Dr. Kolokythas notes that training ratios do not need to be 1:1, that dancers do not need to be as strong in the “turn in” direction as the “turn out” direction, but that some degree of parallel training is necessary. He exemplifies the importance of diversity in building a strong athletic foundation by explaining that track athletes who only compete in the forward direction can improve their linear speed with lateral agility training. When it comes to workout design, more repetitions (at least 12-15) with low load (less than the weight of the athlete) promote muscular endurance, while fewer repetitions with higher weight enhance strength. Dancers can also increase their muscular power with jump training, especially if they do not wish to employ heavy weights.

Dr. Kolokythas regrets the limited body of evidence available to support his recommendations and the low quality of that which does exist. Even so, there is more research about aerobic training than there is about strength training. Though this is likely due to the rejection of potential muscular hypertrophy, data that discount bulking up should assuage any hesitation. He ultimately reaffirms that the dance community would benefit from more systematic reviews, citing hip intervention work at the Australian Ballet as model research to guide future studies.

Dr. Susan Mayes, lead physiotherapist for the company, has been conducting this research since she noticed that hip injuries, most of which require surgery and a year-long rehabilitation process, comprised 7% of the Australian Ballet’s injuries. In 2006, Dr. Mayes taught her dancers several different exercises that target and strengthen muscles surrounding the hip. Ballet dancers, specifically, tend to compensate for weak adductors and weak deep external rotators with bulky upper glute quadrants and underutilized lower quadrants, imbalances that are exacerbated by excessive stretching. In fact, injury incidence data led Dr. Mayes to discourage company members from stretching at all—advice that contradicts centuries of traditional theory but that has greatly enhanced the health of the company. Since the implementation of the hip intervention in 2006, there have been no hip arthroscopies or hip surgeries, and no dancers have gone off for hip-related pain since 2012.

Dr. Mayes has been implementing cross-training measures into dancer regimens for as long as she has been with the company, allowing annual injury trends to direct her interventions. Each year she targets the muscle group with the highest rate of injury from the previous season. After 25 years, the dancers now participate in high resistance training for all muscles, focusing on both strength and endurance. The exercises Dr. Mayes prescribes are not necessarily dance-specific. But, through trial and error, she has found that some prove more advantageous when
performed in ballet positions. Most exercises are executed in a series of iterations that progress from general to sport-specific movements. For example, to strengthen their hamstrings, dancers might begin by lying on their back and performing several repetitions of a weighted bridge hip raise before progressing to a single-leg Russian deadlift in parallel. Eventually dancers would advance to the same movement in an arabesque position, with the working and standing legs externally rotated and the chest lifted. Adding a weighted plate held close to the chest and pushing the working leg extension can imitate panché position and strengthen related muscle groups. In teaching these progressions, Dr. Mayes is adamant about educating her dancers on the correlation between basic movements and performance enhancement. For example, a seated leg press can be directly linked to more powerful sautés. Framing exercises this way allows dancers to conceptualize the direct benefits of cross-training which increases participant follow-through and self-efficacy.

All too often, people skip straight to the sport-specific version of an exercise before they have gained adequate strength in neutral positions. For this reason, Dr. Mayes supports the implementation of Pilates (which often imitates balletic movements) into cross-training regimens, though the method’s efficacy has long been disputed. As of 2007, fitness interventions in professional settings often consisted of, “gentle or corrective exercise formats such as Pilates and gyrotonics”13. While Twitchett et al. warn that cross-training methods like Pilates, Feldenkrais, and the Alexander Technique are gaining recognition despite the fact that “they have generally received little scientific validation”17, more recent research suggests otherwise. One study measured the duration and height of front, side, and back développés at the barre for 15 dancers. For the next 11 weeks, dancers in the experimental group performed three sets of 12 repetitions of mat-based Pilates exercises twice a week while the control group maintained their normal technique class schedules. After 11 weeks, both the experimental and control groups underwent identical testing. The control group showed no signs of increased strength or flexibility, but every participant within the experimental group demonstrated growth in both areas, gaining an average of nine seconds and four to ten degrees in their développé holds. Amorim and Wyon attribute core strengthening within the Pilates group to increased use of the abdominal and gluteus muscles as well as continuous engagement of the hip flexors, and they associate increased range of hip movement with increased strength rather than heightened flexibility21. Thus, Amorim and Wyon recommend that dancers take advantage of Pilates technique when conditioning outside of class, because it, “develops capacities crucial for performance without neglecting the artistic component”21. Even so, Dr. Kolokythas maintains that if Pilates was as beneficial as these results suggest, injury incidence would be far lower.

Ultimately, functionality is an end, the means to which include basic high resistance joint strengthening and muscular hypertrophy. Of course, Pilates and other low load recommendations are made with the assumption that dancers are susceptible to fatigue, a condition exacerbated by high resistance training of any sort. Dr. Mayes proposes higher weights with fewer repetitions for any strength exercise so as to decrease the workload and protect against both physical and mental overexertion. Pilates was often paired with high repetition, low load regimens in the past, potentially contributing to the negative perception of its contribution to strength enhancement. Pre-class priming of joint mobilization exercises and the addition of two or three strength training sessions per week at the end of the day might be the best schedule through which to implement this type of training.

Because the Australian Ballet is on tour for five months out of the year, Dr. Mayes cannot rely upon heavy equipment when designing workout plans. When machines are not available,
dancers use TheraBand's and free weights to mimic the effect of more traditional workout equipment. Two “vital bits of machinery” that the dancers miss while on tour are the leg press and leg extension machines which specifically target the lower gluteal muscles so infamously under-utilized and hard to isolate. This kind of adaptability was especially advantageous when the COVID-19 pandemic forced dancers out of studios for several months in early 2020. With more free time and less equipment, dancers did more running, biking, and stair climbing which induced cardiorespiratory benefits and endorphin secretion similar to what they might experience with the excitement of performing on stage. Dr. Mayes also utilized Microsoft Teams as a platform to stream exercise programs for the dancers who were each prescribed an individualized routine.

**FIFA 11 precedent**

Though the Australian Ballet is at the forefront of cross-training research, Dr. Mayes emphasizes the gaps in our knowledge that can only be filled by other companies who are willing to experiment with their own dancers. One barrier that has limited the development of any unified system is the lack of verified performance metrics by which we can measure success in any meaningful way. One precedent for evaluating the validity of training programs in a standardized, sport-wide context was set by authors of “The FIFA 11+ Injury Prevention Program for Soccer Players: A Systematic Review” who sought to validate the credibility of the FIFA 11+ injury prevention program (developed for soccer players by the Fédération Internationale de Football Association (FIFA) Medical Assessment and Research Centre, Oslo Sports Trauma Research Center, and Santa Monica Orthopaedic and Sports Medicine Center in 2006) (Appendix B) by reviewing randomized clinical trials on the subject. Strict inclusion criteria limited the review to six trials performed in Europe, North America, and Africa, but its intent and breadth (6,344 players total) ought to be modeled in similar reviews amongst the ballet dancer population. Though inconsistent results called the efficacy of the FIFA 11+ program into question, Sadigursky et al. determined that it is effective in reducing injury incidence, “as its use led to a 30% reduction in injury occurrences, with an estimate RR of 0.70 (95% confidence interval [CI], 0.52-0.93; p = 0.01)”22. They also noted that heterogeneity might be attributable to “clinical factors inherent to the sample, such as sex, age, body mass index (BMI), […] clinical characteristics of the injuries […] type of warm- up adopted by the [control group], non-blinded trainers, differences in capacity among training teams, and technical managers, as well as study frequency and duration”22. There is a similar need for scientific validation of proposed exercise interventions for dancers; however, more trials must be performed before a meta-analysis could even be considered significant. In fact, Sadigursky et al. concede that even the FIFA 11+ program is limited by the lack of literature to support it as well as its relative newness, stressing the importance of continued research within the specific population of interest22.

Nawed et al. discuss the benefits of the FIFA 11+ program in terms of decreased rates of injury but admit that any preventative program ought to improve performance as well, in order to promote coach and player participation and follow through23. The distinction between injury prevention and performance enhancement as documented by Lees" seems to support this stance. In 2018, Nawed et al. attempted to rectify the disparity between both measures by conducting a study on 57 amateur male soccer players from Jamia Hamdard University. Over the course of 12 weeks, half of the men completed a standard 20-25 minute warm up while the other half performed the 20-25-minute FIFA 11+ program. A vertical jump test, 20-meter sprint run test, t-
test, and Illinois agility run test were conducted both before and after the intervention period to assess leg power, speed, and agility. Results indicated that the FIFA 11+ program is effective at increasing leg power and sprint speed (as indicated by vertical jump and 20-meter sprint scores) but not necessarily agility (as measured by both the t-test and Illinois agility test). The authors link these data to increased performance amongst experimental group players, suggesting that because “the ability to jump higher to head the ball, run faster with or to the ball, and change direction are critical in scoring and defending the goal in soccer […] interventions that improve these measures can enhance the players’ performance during competitions”23. Though their study was predicated upon the difference between enhanced performance and injury reduction, any distinction they attempt to make between the terms is convoluted at best by undifferentiated results that seem to support both. Another meta-analysis performed by Gomes Neto et al. examined the effects of FIFA 11 (a primitive version of the FIFA 11+ program) on 4700 football players in 11 different trials24. Results indicated that FIFA 11 improved balance and agility, but that any improvements in jump height and running sprint speed were not statistically significant. They ultimately determined that FIFA 11 can be used to reduce injury incidence24 but did not cite it as a means of improving power or speed. These interpretations suggest that balance and agility correlate with injury prevention specifically, thus implying that jump height and sprint speed correlate with performance enhancement alone.

Confounding results question both the validity of conclusions made by Nawed et al. and Gomes Neto et al. as well as the definitions of performance enhancement and injury prevention that guide our current research. Gomes Neto et al. cite the relative lack of football-related studies as a potential limitation to their conclusions and warn that, “caution is warranted when interpreting [their] results”24. The abstract nature of such research seems to suggest that injury prevention is much more easily documented than any improvement in performance parameters. For example, Sadigursky et al. discuss injuries in terms of their incidence and bodily location amongst soccer and ballet athletes22, and Nawed et al. judged the FIFA 11+ program by its ability to promote those activities necessary for scoring23. But, there are no comparable, quantifiable goals within dance, and neither group offered similar metrics for the comparison of performance enhancement. And even if performance quality was a more objective concept in general, the unique nature of dance (as discussed by Tiemens et al.18) in contrast to most other goal-oriented sports suggests that judging ballet performance provides a unique challenge irrespective of those posed by abstract definitions. These shortcomings provide further incentives for additional, sport-specific research that differentiates between two different potential benefits of cross training.

11+ Dance

Dr. Kolokythas is one professional who has lamented these deficiencies. Modeled after the FIFA 11+ program, his 11+ Dance regimen (Table C1) addresses part of the gap, particularly in terms of injury prevention as opposed to performance enhancement. FIFA 11+ was originally designed to address the disproportionate percentage of soccer player injuries that occur within the first and last 15 minutes of competitive play22. This temporal pattern of injury suggests that, much like injuries recorded in dancer populations, the most common injuries amongst soccer players are those associated with fatigue, inadequate warm-up, and muscular imbalance, especially of the lower limbs. These similarities suggest that dance and soccer are not as disparate as they seem and might allow relevant comparisons to be made between injury prevention methods. Although
it was intended to benefit soccer players, “several studies demonstrated [FIFA 11+’s] effectiveness for other sports such as basketball”\textsuperscript{22}, and Dr. Kolokythas adapted it even further when he marketed similar exercises to dancers. FIFA 11+ consists of 15 exercises that enhance core stability, eccentric thigh muscle strength, proprioception, and plyometrics. \textit{11+ Dance} consists of two sessions of 14 and 12 exercises respectively. Both programs are approximately 20 minutes in duration and intended to be performed at least twice a week (Table C2). Dr. Kolokythas promotes the use of sport-specific training for dancers of all levels with \textit{11+ Dance} in contrast to Wyon, who suggests that the American College of Sports Medicine’s generalized standards for health maintenance are adequate supplementary training guidelines for students and recreational dancers and are only insufficient when it comes to the professional demographic\textsuperscript{15}.

In a personal interview, Dr. Kolokythas suggested that rather than performing research as an end in itself, dance medicine professionals ought to explore those issues that would most enhance the lives of dancers when resolved - research as a means to an end. And, the more “methodologically robust” that research is, the more likely practitioners are to implement conclusions into their recommendations and treatment plans. Dr. Kolokythas specifically mentions studies being done at his own company, the Birmingham Royal Ballet, as well as the aforementioned work of Dr. Susan Mayes with the Australian Ballet as potential sources for credible data, maintaining that the most useful information for professional dancers will come from professional companies themselves.

\textbf{USFS & USAG standards}

While Dr. Kolokythas derived his recommendations from those originally intended to benefit soccer players, Liederbach and others have demonstrated distinct differences in these populations\textsuperscript{25}. Dancers suffer far fewer ACL injuries than athletes in team ball sports like soccer and basketball. Because ballet might actually protect against ACL injuries, supplementary training for ballet may not need to target balance and landing mechanics as much as training for other sports\textsuperscript{25}. So, while FIFA 11+ provides a basis from which recommendations might be made, discontinuities amongst target populations might limit the effectiveness of associated interventions. Gymnastics and figure skating are two aesthetic sports perhaps more comparable to ballet that have their own set of fitness recommendations. Nationally standardized intervention plans put forth by the governing bodies of both sports serve as examples of how programs like \textit{11+ Dance} might be incorporated into a consistent, regulated national standard. U. S. Figure Skating (USFS) is recognized by the United States Olympic Committee as America’s national governing body for the sport of figure skating. The USFS website includes standardized information on injury prevention, overtraining and recovery, and nutrition that is readily available to the public. Their Standardized Testing of Athleticism to Recognize Skaters (S.T.A.R.S.) program consists of fourteen tests that measure agility, balance, coordination, strength, power, and flexibility off the ice (Appendix D). The U.S. Figure Skating YouTube channel also has three “Off-Ice Training” videos that guide participants through a series of exercises for core, foot and ankle, and shoulder stability (Video F1). In addition, USFS employs the High-Performance Movement Screen (HPMS) in injury prevention efforts which assesses mobility, stability, and symmetry with the y-balance test, single leg squat test, rotary stability test, shoulder mobility test, hip mobility test, and balance error scoring system (Appendix E). Any USFS skater can receive an individual screening with a physician, physical therapist, or certified athletic trainer to identify potentially injury-inducing weaknesses\textsuperscript{26}.
Much like the USFS, USA Gymnastics (USAG) offers the USAG Fitness Program as a means of enhancing athlete fitness and overall health (Appendix G). The handbook discusses basic gymnastics skills and the fitness fundamentals they are built upon, namely aerobic exercise, movement, strength training, flexibility and nutrition. While dance professionals address a lack of verified fitness metrics and baseline measurements within their community, USAG specifically discusses ways to determine fitness levels and set fitness goals before starting the program which itself offers a series of cardiovascular games; movement exercises for sprint mechanics, lateral movements, and plyometrics; strength training exercise progressions for the core, glutes, squats, lunges, push-ups, pull-ups, total body, and static flexibility; and nutrition advice. Although it is marketed towards 3-16-year-old recreational, club, and team gymnasts instead of professionals, the program still exemplifies a concerted effort to promote athlete wellbeing by a governing body. Ballet lacks any similar regulation regarding standardized resources for athlete wellness.

Injury incidence

Creating a widely accepted standard for fitness amongst dancers would facilitate coordination amongst professional companies and medical teams and provide guidelines from which future recommendations and research could be based. Without a means by which comparisons can be made, it will be nearly impossible to launch a concerted effort to enhance dancer wellness. Although research has demonstrated a need for supplementary training, the available evidence conveys injury prevalence and strength deficits more than it suggests how to overcome these limitations. Clanin et al. found that 159 dancers sustained 335 injuries over the course of two years8. Ramkumar et al.27 and Koutedakis et al.8 both conducted incidence studies that identified lower back and lower extremity injuries as the two most prevalent. Additionally, Stacciolini et al. stress the need for injury prevention over treatment by citing injury incidence data for both pre-professional and professional populations (0.77 to 1.55 per 1,000 dance hours and 0.60 to 0.62 per 1,000 dance hours respectively). Even then, they warn that an inconsistent definition of “injury” reduces the efficacy of data interpretation. The authors continue on to debunk several misconceptions about resistance training for dancers, namely that it is unsafe for children, induces bulky muscles, does not benefit young females, and that there is one right way to perform the exercises25. However, they fail to suggest possible alternatives when making this claim.

Yet another example of research that must be extended beyond tracing incidence into providing a tangible product is that of Allen et al. who employed Van Mechelen’s injury prevention model, the Functional Movement Screen (FMS), and lead author, Nick Allen M.Sc.’s, Hybrid Intervention Model (HIM) in evaluating the validity of an injury prevention program amongst professional ballet dancers10. Van Mechelen’s model establishes the progression of preventative measures from determining the extent and etiology of the injury to introducing preventative measures and assessing success by revisiting the incidence and severity of the injury after treatment. The FMS is a generalized assessment that measures mobility and predicts injury occurrence with seven basic exercises (Appendix H). Implemented in year one of the study, participants performed a deep squat, hurdle step, in-line lunge, trunk stability pushup, shoulder mobility stretch, active straight-leg raise, and rotary stability sequence. FMS results guided HIM-based injury prevention efforts through years two and three of the study. Conceived as a means of designing personalized strength training regimens, the HIM is applicable to both rehabilitative
and maintenance-oriented conditioning programs. It addresses neuromuscular facilitation, isolated segmental deficit training, and functional integration as they relate to the injury itself, the cause of injury, and the desired outcome.  

Fifty-eight dancers in a professional ballet company participated from 2005 to 2008. Dancers performed 145 times, 143 times, and 142 times in years one, two, and three respectively. They were all injury-free at the beginning of year one. Following HIM implementation, injury progression was audited. 355 injuries were reported in year one, decreasing to 183 in year two and 174 in year three despite an increase in overall exposure to dance (as measured by allowable dance-related activity). A Poisson distribution model confirmed the significance of rate differentials. Though injury severity (as measured by injury-related days-off of work) increased slightly each year, the incidence of recurrent injuries as a proportion of the total declined by 15%. In addition, the authors suggest that the increase in severity reflects a greater understanding of the necessary rehabilitation time for comparable injuries rather than injuries with worse prognoses.

Though the HIM was developed based upon “key performance attributes from elite sport and dance [and combines] the skill and ‘efficiency of movement’ characteristics noted with elite dancers, together with the fitness and strength attributes of ‘traditional’ elite sports athletes,” Allen et al. do not address the degree to which it is dance-specific. In fact, the authors admit that a “notable aspect of the FMS in relation to other dance screening is the absence of any dance specific testing” but reaffirm that they “chose a normal movement screening to establish the nature of movement outside of the skill and technique as a dancer to provide a more accurate indication of risk for when their skill or technique is diminished for any reason [as by fatigue].” In this case, Allen et al. cite the lack of specificity as a strength rather than a weakness. In addition to generalized measurement models, Allen et al. further claim that a broad strengthening program helps dancers “be better conditioned to withstand the rigors of modern-day elite level ballet.” While the deep squat and in-line lunge tests of the FMS both helped practitioners identify sacroiliac instabilities, the authors maintain that the importance of dance-specific measures cannot be understated in the treatment of this specific population.

Conclusions

Dr. Nancy Kadel supports the push for company-funded research and solution-based thinking. In a personal interview, she expressed the need for professional companies with both adequate funding and sufficient buy-in from dancers and management who are willing to participate in such studies. In fact, she blames the current lack of coordinated regulation amongst companies and health professionals for perpetuating inefficiencies in the provision of quality care. In order to clarify loosely defined recommendations, Dr. Kadel reiterates the need for company-wide studies, specifically year-long interventions with control and experimental groups. In companies that are willing to invest in research like this, half of the dancers should act as the experimental group (performing a prescribed conditioning program) while the other half acts as the control group with no change to their training schedules. She specifically mentions work done by Dr. Matthew Wyon who studied the effects of one hour of conditioning class in an experimental group substituted for an additional hour of dancing in the control group. This study design should guide future research for programs who prescribe any hour-long training regimen under question to one group of dancers and compare fitness outcomes to another group who dances for an additional hour instead. In another personal interview, athletic trainer with the Harkness Center
for Dance Injuries, Josh Honrado, DAT, MS, ATC, CSCS, RYT, discussed the need for more studies on pointe shoe readiness, lifting and partnering preparedness, plyometric training to promote better jumping, and the disparate effects of petite versus grande allegro movements. Much like Dr. Kolokythas, Dr. Mayes, and Dr. Kadel, Dr. Honrado recognizes that the most applicable data will come out of in-house research amongst the population of interest but admits that the Harkness Center is not currently performing this type of research, focusing more on epidemiology, jump landing biomechanics, and spinal motion instead.

Of course, Dr. Mayes is careful to stipulate that even the research done with professional companies will not be dependable until the testing methods themselves have been validated. She suggests that one way to assess the validity of a test would be to perform it on both dancer and non-dancer athletic populations and determine whether or not comparable results were obtained. Based off of the intervention already created for soccer players, Dr. Kolokythas’ 11+ Dance is one program that exemplifies how this might be done.

Alvin Ailey is one professional company that is prioritizing physical fitness as a preventative measure against injury-related losses. Data collected in an experiment conducted from 1998 to 2001 were contrasted with comparative statistics from 1996 and 1997. In both years directly preceding the intervention, Alvin Ailey dancers did not have access to on-site medical professionals when they suspected injury. They either sought treatment at an emergency department or received a referral for private practice physical therapy through an orthopedic surgeon associated with the company. In years three, four, and five, dancers had access to primary preventative measures like annual dance-specific fitness screenings, technique allowances, cross-training, and medical advice for minor ailments. Secondary preventative measures were also improved to provide more coordinated treatment and rehabilitation. Physical therapists saw patients in-house at rehearsals, backstage at performances, and on the go during the US touring season. Introduction of the intervention resulted in a drop of new worker’s compensation claims from 79-81% to 17% in year five. Total injuries per 1,000 hours of dance, regardless of insurance status, declined as well, falling from 0.51 in year one to 0.18 in year five.

Like Alvin Ailey, other professional companies are starting to recognize the importance of research like this. In fact, although the COVID-19 pandemic forced many companies off the stage and out of the studio for several months in 2020 and 2021, it also provided a unique opportunity for companies to experiment with cross-training when they were forced to address the physical deficits that accompanied quarantine stay-at-home regulations. Dr. Kolokythas commented that his dancers focused more on strength training during quarantine than ever before, both because they did not have access to their usual facilities and because they had more energy and free time without the burden of their typical training schedules. When dancers were allowed back into the studio, teachers and health professionals worried that a quick return to normal training would result in increased injury rates. Dr. Mayes attributed this pattern in injury incidence to the fact that most dancers were careful at home and naturally more guarded on un-sprung floors but were overzealous when they returned to the more supportive marley flooring of their studios. Surprisingly, Dr. Mayes was more worried about the demands of petite allegro than those of grand allegro. While the traveling aspect of grand allegro posed an injury threat for those dancers who had been confined to approximately one square meter at home, Dr. Mayes cited the speed and accuracy required in petite movements as riskier than the height required in grand combinations. Her protocol for dancers returning to normal work was much like that of dancers rehabbing an injury: begin training allegro in place with lower pirouette complexity,
fewer traveling sequences, and a fairly normal barre warm-up; progress to grand allegro with a slow speed; and, eventually, add fast petite allegro. When Australian Ballet dancers first came back to work after a second wave of COVID-19 in Melbourne, they had an hour to use strength equipment in the studio, then class and rehearsal before another hour in the gym.

While increased injury rates were, in fact, observed in conjunction with loosening lockdown restrictions (regardless of professional status), heightened concern catalyzed the kind of coordinated communication that dance medicine has lacked thus far. Both the Harkness center for Dance Injuries and IADMS posted educational content on various social media platforms throughout lockdown. The Harkness Facebook page has links to several livestreams with health professionals who discuss aerobic training and mental health. Ashley Houck, PT; Rebecca Kesting, MD, PT; and Lauren McIntyre, AT discuss the risks and benefits of different cardiovascular training methods in a video posted on June 12, 2020 (Video F2). Much like Wyon et al., they justify training to supplement the relatively low level of aerobic endurance developed through class alone. Similarly, IADMS created a YouTube playlist entitled “Performing Artists’ Mental Health and COVID-19” with videos discussing sleep, stress, and depression (Video F3). Another series of videos, “Safe Dance Practice Live Panels”, addresses dance education, safe dance practice during quarantine, and conditioning in the context of a global pandemic (Video F4). Dr. Kolokythas was one guest panelist along with Stevie Oakes, MFA, CSCS, and Dr. Robert Tsai, PT, DPT. The panelists discuss skill as a function of endurance, strength, function, and speed.

Although this influx of educational information is necessary and has been long-awaited in the dance community, all three IADMS panelists emphasize the importance of media literacy and context when choosing which resources to trust and which conditioning methods to adopt. Dr. Tsai endorses “purpose” and “intention” as the guiding pillars of his practice as a healthcare provider. Much like Dr. Mayes, he ensures that his dancers know why they are doing what they are doing. Oakes asks dancers to be judicious in deciding which strength coaches and teachers to trust (What are their affiliations? What other resources do I already know and trust?) and to use their intuition (How does this resonate with me? Does it make sense to me? How do I feel?) in order to be discerning about the media content they use. Dr. Kolokythas recommends that dancers ask a different set of questions (How full is the [social media] post? Is it taking me through the whole process so that I can understand why I’m seeing what I’m seeing? Is there a start and an end? Does it explain the why behind the movement?). He emphasizes that follower count is not an adequate metric when determining the credibility of fitness accounts and suggests that dancers and dance educators alike seek direct advice from medical professionals like himself instead of taking fitness into their own hands. In fact, Dr. Kolokythas posits that global lockdown during the COVID-19 pandemic “could be an opportunity for further collaborations and actually open the door to a multidisciplinary […] and holistic approach of dancer development” (Appendix F, Video F4).

To wrap up the panel, moderator Ellie Kusner, MSc, asked, “in the face of not having to be performance ready, what can we do with this time […] how do we think strategically about fitness?” While the current state of the world has revolutionized the ways in which we approach art, ballet has always been a dynamic reflection of society. It was conceived at a crossroads between the Renaissance and Enlightenment eras in Europe and has evolved in the context of social, cultural, and political upheavals in the centuries since. Ballet will continue to reflect the conditions in which it exists, especially in an age of enhanced access, visibility, and communication in which the resources and tools our dancers need to become stronger athletes
and better performers are more accessible than ever before. In the face of not having to be performance ready, then, we can shift from the limited, dichotomic perception of dancers as either performance ready or not and begin to focus on their athleticism, strength, tenacity, and fortitude as artists and people with strong ties to our past and important implications for our future.
References


Appendix A. Verkhoshansky’s block periodization model

Verkhoshansky’s Standard Model for the Main Adaptation Cycle Model

\[ W = \text{Work Power} \quad \text{Vol} = \text{Volume} \quad f = \text{Maximal level of functional parameters} \]
Appendix B. FIFA 11+ injury prevention program
Appendix C. *11+ Dance description and comparison*
Retrieved from: https://www.strengthmotionmind.com/11-dance

All credit to Dr. Nico Kolokythas, ASCC, PhD

**Table C1. 11+ Dance description**

**Session 1**

*only challenge yourself with progressions if you can maintain a neutral spine and/or knee alignment in basic position*

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Skip</td>
<td>Skip for three 1-minute sessions with rest intervals of 15-20 seconds in between. Focus on landing with both feet at the same time.</td>
</tr>
<tr>
<td></td>
<td><strong>Progressions:</strong></td>
</tr>
<tr>
<td></td>
<td><em>Alternate skips:</em> perform one skip on each leg, alternating every time.</td>
</tr>
<tr>
<td></td>
<td><em>Single-leg serial skips:</em> perform two to three consecutive skips on one leg, then switch legs.</td>
</tr>
<tr>
<td>2. Plank on Elbows</td>
<td><strong>Progressions:</strong></td>
</tr>
<tr>
<td></td>
<td><em>Raise opposite hand &amp; leg</em></td>
</tr>
<tr>
<td></td>
<td><em>Plank rotations:</em> open up shoulder and hip to face one side while keeping toes planted.</td>
</tr>
<tr>
<td>3. Side Plank with Bent Knee</td>
<td><strong>Progressions:</strong></td>
</tr>
<tr>
<td></td>
<td><em>Side plank with straight leg:</em> extend bottom leg so that both feet are planted, hold plank position.</td>
</tr>
<tr>
<td></td>
<td><em>Elbow to knee:</em> touch the elbow on top arm to the knee on top leg by bringing both limbs together in line with stomach.</td>
</tr>
<tr>
<td>4. Bridge</td>
<td><strong>Progressions:</strong></td>
</tr>
<tr>
<td></td>
<td><em>Bridge with steps:</em> raise alternate legs with pointed toes.</td>
</tr>
<tr>
<td>Exercise</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>5. Hamstring Raises</td>
<td><strong>Bridge with knee extension:</strong> raise alternate legs with pointed toes, extend the knee before returning to bent position.</td>
</tr>
</tbody>
</table>
|                                                           | **Bridge with knee extension & hold** (3-5 sec).
<p>| Progressions:                                             | Repeat with feet further away from glutes.                                                                                                                                                                    |
|                                                           | Single leg: raise one leg at a time; alternate legs.                                                                                                                                                           |
| 6. Squats to Demi-Pointe                                  | Perform a regular squat, returning to demi-pointe relevé instead of flat-footed stance. Maintain natural turnout with feet shoulder width apart.                                                              |
| Progressions:                                             | Slow descent with explosive intention upwards: use four counts to reach bottom of squat.                                                                                                                                 |
|                                                           | Pause at bottom.                                                                                                                                                                                             |
|                                                           | Single leg demi-pointe: perform regular squat, return to demi-pointe parallel passedé, alternate legs.                                                                                                          |
| Progressions:                                             | Demi-pointe: return to demi-pointe after every lunge.                                                                                                                                                        |
|                                                           | Développé before lunge: perform développé on demi-pointe before each lunge.                                                                                                                                  |
|                                                           | Lunge rotations: turn 360 degrees towards back leg after each lunge, landing in the alternate leg lunge.                                                                                                        |
| 8. Side Lunges                                            | Alternate legs and maintain natural turnout.                                                                                                                                                                  |
| Progressions:                                             | Side to cross body: step out of lunge, and bring bent leg across to other side of body, bending both knees one over the other.                                                                               |
| 9. Single Leg Balance with Hip Rotations                  | Stand with both elbows behind head and one leg extended straight out from the hip with                                                                                                                       |</p>
<table>
<thead>
<tr>
<th>Progressions</th>
<th>Bent knee. Maintain body position while opening and closing knee.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>10. Cross-Country Skiing</strong></td>
<td>Balance on one leg with the other knee extended in line with hip. Raise opposite arm, bent at elbow. Extend raised leg back as far as possible while bending supporting leg and lowering chest so as to maintain a straight line from toe to head.</td>
</tr>
<tr>
<td><strong>Upper body rotation</strong></td>
<td>Maintain closed, raised knee position while rotating head and shoulders from one side to another.</td>
</tr>
<tr>
<td><strong>Overhead reach</strong></td>
<td>Perform cross-country ski, reaching arms in a straight line from toe to finger when in the extended position.</td>
</tr>
<tr>
<td><strong>11. Hip Airplane</strong></td>
<td>Extend one leg behind you in line with bowed chest while balancing on the opposite bent leg. Extend arms to either side and open up chest to alternating sides.</td>
</tr>
<tr>
<td><strong>12. Forward Landings</strong></td>
<td>Jump with both feet from a standing position, landing in a parallel squat.</td>
</tr>
<tr>
<td><strong>Freeze the landing</strong></td>
<td>Hold the squat position upon landing before making the next jump.</td>
</tr>
<tr>
<td><strong>One forward, one up</strong></td>
<td>Perform squat jump in place; alternate with forward landing jumps.</td>
</tr>
<tr>
<td><strong>13. Side Landings</strong></td>
<td>Jump to the side with both feet remaining front-facing and parallel; land in squat position.</td>
</tr>
<tr>
<td><strong>Rotations</strong></td>
<td>Land in squat facing alternate directions each time.</td>
</tr>
<tr>
<td><strong>14. Single Leg Landings</strong></td>
<td>Perform forward landing squat jump, landing in single-leg squat with opposite leg bent either in front or behind the body.</td>
</tr>
<tr>
<td><strong>One forward, one up</strong></td>
<td>Perform single-leg forward jump alternating with single-leg straight jump.</td>
</tr>
<tr>
<td><strong>Left right stick</strong></td>
<td>Jump to the side, landing on outside leg with opposite leg bent in front of</td>
</tr>
</tbody>
</table>
the body; alternate directions, pausing after every third jump.

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. Single Leg Side Landings</td>
<td>Perform side landing jump, landing on outside leg and bending opposite leg.</td>
</tr>
<tr>
<td>Progressions:</td>
<td><em>One side, one up:</em> after landing from single-leg side landing jump, push off of landing leg into a vertical jump.</td>
</tr>
<tr>
<td></td>
<td><em>Step-cross-jump:</em> perform tombé pas de bourrée sequence in front of body before performing a single-leg side landing jump.</td>
</tr>
</tbody>
</table>

Session 2
*only challenge yourself with progressions if you can maintain a neutral spine and/or knee alignment in basic position

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Plank on Hand with Elbow Taps</td>
<td>Tap one elbow with the opposite hand; alternate hands.</td>
</tr>
<tr>
<td>Progressions:</td>
<td><em>Shoulder taps with pause:</em> remain in single-arm pushup position before alternating.</td>
</tr>
<tr>
<td>2. Bear Crawls</td>
<td>Begin with toes and hands on the floor, lifting one hand off at a time to maintain three points of contact with the ground.</td>
</tr>
<tr>
<td>Progressions:</td>
<td><em>Small steps forwards and backwards:</em> bring one hand and the opposite leg forward before returning to neutral and alternating sides.</td>
</tr>
<tr>
<td></td>
<td><em>Repeat the same motions in the backwards direction as well.</em></td>
</tr>
<tr>
<td></td>
<td><em>Crawling:</em> perform a bear crawl straight forward or backwards.</td>
</tr>
<tr>
<td></td>
<td><em>Travel in different directions:</em> maintain the bear crawl posture while traveling in multiple directions.</td>
</tr>
<tr>
<td>3. Crab Walks</td>
<td>Begin in the crab walk position and alternately raise each hand and each leg.</td>
</tr>
<tr>
<td>Progressions:</td>
<td><em>Small steps forwards and backwards:</em> bring one hand and the opposite leg forward before returning to neutral and alternating sides.</td>
</tr>
<tr>
<td>33</td>
<td>Repeat the same motions in the backwards direction as well.</td>
</tr>
<tr>
<td>----</td>
<td>------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td><em>Walking:</em> perform a crab walk straight forward or backwards.</td>
</tr>
<tr>
<td></td>
<td><em>Travel in different directions:</em> maintain the crab walk posture while traveling in different directions.</td>
</tr>
<tr>
<td></td>
<td><em>Faster:</em> continue walking at a faster pace.</td>
</tr>
</tbody>
</table>

4. **Cook Hip Lifts**

Lay on back with knees bent, as if you are about to perform a sit-up. Lift glutes off the ground in line with knees and shoulders and draw one knee into chest. Lower and raise glutes while holding knee at chest.

5. **Monster Walks**

Wrap a resistance band around ankles. Step out with one leg before bringing the other to meet it.

**Progressions:**

- *All four directions:* step forward and backwards in a similar motion.
- *Soft knees:* repeat the side steps with bent knees.
- *Soft knees, all four directions:* repeat the forward and backward steps with bent knees.
- *Demi-pointe:* repeat the side steps on relevé.
- *Demi-pointe, all four directions:* repeat the forward and backward steps on relevé.

6. **Deep Squats with Overhead Reach**

Squat beyond a ninety-degree angle. Extend your arms above your head once you reach the deepest point of your squat.

**Progressions:**

- *Squeeze hands together:* repeat the deep squat with hands above head throughout the entire movement, pressed together as if you were about to dive into a pool.
- *Push hands outward with resistance band:* repeat the deep squat with your hands above head throughout the entire movement,
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Side Slides</td>
<td>pushing outward against a resistance band looped around wrists.</td>
<td>Perform a side lunge. Instead of returning to planted foot, bring extended leg to meet bent leg so that you travel to one side or the other.</td>
</tr>
<tr>
<td></td>
<td>Progressions:</td>
<td>Pause at bottom</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Raise leg on way up</td>
</tr>
<tr>
<td>8. Leg Swings</td>
<td>Stand on one leg while swinging the other back and forth with knee slightly bent.</td>
<td>Cross-body swings: swing leg medially and laterally instead of forward and backwards.</td>
</tr>
<tr>
<td></td>
<td>Progressions:</td>
<td></td>
</tr>
<tr>
<td>9. Single Leg Reach</td>
<td>Squat with one bent leg and one extended in tendu with pointed toes to the front of the body. Repeat to the side, back, and opposite side, maintaining center of balance above bent leg.</td>
<td></td>
</tr>
<tr>
<td>10. Forward Landings</td>
<td>Jump with both feet from a standing position, landing in a parallel squat</td>
<td>Freeze the landing: hold the squat position upon landing before making the next jump.</td>
</tr>
<tr>
<td></td>
<td>Progressions:</td>
<td>One forward, one up: perform squat jump in place; alternate with forward landing jumps.</td>
</tr>
<tr>
<td>11. Side Landings</td>
<td>Jump to the side with both feet remaining front-facing and parallel; land in squat position.</td>
<td>Rotations: land in squat facing alternate directions each time.</td>
</tr>
<tr>
<td></td>
<td>Progressions:</td>
<td></td>
</tr>
<tr>
<td>12. Single Leg Landings</td>
<td>Perform forward landing squat jump, landing in single-leg squat with opposite leg bent either in front or behind the body.</td>
<td>One forward, one up: perform single-leg forward jump alternating with single-leg straight jump.</td>
</tr>
<tr>
<td></td>
<td>Progressions:</td>
<td>Left right stick: jump to the side, landing on outside leg with opposite leg bent in front of the body; alternate directions, pausing after every third jump.</td>
</tr>
</tbody>
</table>
### 13. Single Leg Side Landings

**Perform side landing jump, landing on outside leg and bending opposite leg.**

**Progressions:**

- *One side, one up:* after landing from single-leg side landing jump, push off of landing leg into a vertical jump.

- *Step-cross-jump:* perform tombé pas de bourée sequence in front of body before performing a single-leg side landing jump.

### Table C2. Comparison of FIFA 11+ and 11+ Dance interventions

<table>
<thead>
<tr>
<th></th>
<th>FIFA 11+ (20 min total)</th>
<th>11+ Dance (25-30 min total)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>To be performed at least twice per week before regular training</td>
<td>To be performed at least twice per week Retrieved from:</td>
</tr>
<tr>
<td></td>
<td>Retrieved from:</td>
<td>Retrieved from:</td>
</tr>
<tr>
<td><strong>Running Exercises</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>(8 min duration)</strong></td>
<td><strong>Muscle Activation</strong></td>
</tr>
<tr>
<td></td>
<td>Straight ahead (x2)</td>
<td>Skip (1 min x3)</td>
</tr>
<tr>
<td></td>
<td>Hip out (x2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hip in (x2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Circling partner (x2)</td>
<td>Session 1</td>
</tr>
<tr>
<td></td>
<td>Shoulder contact (x2)</td>
<td>*each exercise has several iterations depending on skill level and target performance</td>
</tr>
<tr>
<td></td>
<td>Quick forwards &amp; backwards (x2)</td>
<td></td>
</tr>
<tr>
<td><strong>Strength, Plyometric, &amp; Balance Exercises</strong></td>
<td><em>(10 min duration)</em></td>
<td>Plank on elbows</td>
</tr>
<tr>
<td></td>
<td>*each exercise has three iterations depending on skill level and target performance</td>
<td>Side plank</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bridge</td>
</tr>
<tr>
<td></td>
<td>Bench (x3)</td>
<td>Hamstring raises</td>
</tr>
<tr>
<td></td>
<td>Sideways bench (x3)</td>
<td>Squats to demi-pointe</td>
</tr>
<tr>
<td></td>
<td>Hamstrings (x1)</td>
<td>Lunges</td>
</tr>
<tr>
<td></td>
<td>Single-leg stance (x2)</td>
<td>Side lunges</td>
</tr>
<tr>
<td></td>
<td>Squats (x2)</td>
<td>Single-leg balance</td>
</tr>
<tr>
<td></td>
<td>Jumping (x2)</td>
<td>Cross-country skiing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hip airplane</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Forward landings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Side landings</td>
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<tr>
<td></td>
<td></td>
<td>Single-leg landings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Single-leg side landings</td>
</tr>
<tr>
<td><strong>Running Exercises</strong></td>
<td><strong>(2 min duration)</strong></td>
<td>Session 2</td>
</tr>
<tr>
<td></td>
<td>Run length of soccer field (x2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bounding runs (x2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plant &amp; cut runs (x2)</td>
<td></td>
</tr>
</tbody>
</table>
*Each exercise has several iterations depending on skill level and target performance*

<table>
<thead>
<tr>
<th>Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plank on hands with elbow taps</td>
</tr>
<tr>
<td>Bear crawls</td>
</tr>
<tr>
<td>Crab walks</td>
</tr>
<tr>
<td>Cook hip lift</td>
</tr>
<tr>
<td>Monster walks</td>
</tr>
<tr>
<td>Deep squats with overhead reach</td>
</tr>
<tr>
<td>Side slides</td>
</tr>
<tr>
<td>Leg swings</td>
</tr>
<tr>
<td>Single-leg reach</td>
</tr>
<tr>
<td>Side landings</td>
</tr>
<tr>
<td>Single-leg landings</td>
</tr>
<tr>
<td>Single-leg side landings</td>
</tr>
</tbody>
</table>
Appendix D. U.S. Figure Skating S.T.A.R.S. Manual

**INTRODUCTION**

Welcome to the U.S. Figure Skating S.T.A.R.S. Program. S.T.A.R.S. (Student Teaching As A Resource System) is a comprehensive program for assessing student performance in the sport of figure skating. The program was developed in 1990 by the U.S. Figure Skating Sports Science Environment Medical Committee along with the National Strength & Conditioning Association.

The U.S. Figure Skating S.T.A.R.S. Program was designed to be used by coaches, judges and athletes to evaluate and improve the performance of skaters throughout their skating careers. The program encourages coaches and skaters to work together to develop a system of performance measurement and improvement.

The S.T.A.R.S. Program includes a set of criteria that are evaluated during competitions and training sessions. The criteria are designed to assess the skater's technical skills, artistic expression, and overall performance. The program also includes guidelines for coaches and skaters on how to use the criteria to improve their skating performance.

**ASSESSMENT CRITERIA**

S.T.A.R.S. is an assessment system designed to support U.S. Figure Skaters in the development of skills and performance goals. It includes a series of criteria that are evaluated during competitions and training sessions. These criteria are designed to assess the skater's technical skills, artistic expression, and overall performance. The program also includes guidelines for coaches and skaters on how to use the criteria to improve their skating performance.

**ASSESSMENT CRITERIA**

- **EXECUTION**: The skater's technical skills, including jumps, spins, and footwork, are evaluated.
- **ARTISTIC EXPRESSION**: The skater's ability to express themselves through their skating is assessed.
- **PERFORMANCE**: The skater's overall performance, including their routine, is evaluated.
- **GENERAL RELEVANCE**: The skater's ability to apply their skills in different situations is assessed.

**EQUIPMENT AND ATTIRE**

S.T.A.R.S. is designed to be used in conjunction with the U.S. Figure Skating Competition Rules and other relevant regulations. The program includes guidelines for coaches and skaters on how to use the criteria to improve their skating performance.

**CONTENTS AND CALCULATION**

S.T.A.R.S. creates relevance and context through a combination of rules and calculated variables and factors with a stress on the individual athlete. The program is designed to be used during competitions and training sessions. The criteria are evaluated during competitions and training sessions. The program includes guidelines for coaches and skaters on how to use the criteria to improve their skating performance.

**RESEARCH AND RESULTS**

The program includes a research component that provides evidence for the validity and reliability of the S.T.A.R.S. criteria. The research component includes a series of studies that have been conducted to assess the validity and reliability of the program.

**TABLE OF CONTENTS**

- **Execution**
  - Jump
  - Step**
  - Spin
  - Spin
  - Step

- **Artistic Expression**
  - Free skate
  - Free skate

- **Performance**
  - Free skate

- **General Relevance**
  - Free skate

**COVERING SEASON AND PARTICIPATION**

In keeping with a focus on attention, S.T.A.R.S. assessments are conducted during a single skaters’ season. The S.T.A.R.S. assessment is a flexible tool that can be used to assess the skater's technical skills, artistic expression, and overall performance. The program includes guidelines for coaches and skaters on how to use the criteria to improve their skating performance.
HEXAGON JUMP

EQUIPMENT
- Hexagon template, paper, tape, stopwatch

SET-UP
Place the hexagon template flat on the floor. Using marks on the floor or the hexagon shape, set up a target on the floor or an object. The hexagon template should be placed on the floor or an object. The distance between the starting line and the object should be 45 cm.

ASSESSMENT OBJECTIVE
- Recorded time for one trial
- Record the number of successful trials

ASSESSMENT PROTOCOL
1. The athlete stands on the starting line with feet shoulder-width apart.
2. The athlete performs a jump by lifting one leg and crossing one leg over the other.
3. The athlete jumps over the hexagon template and places the foot on the hexagon template.
4. The athlete jumps over the hexagon template again and returns to the starting line.

VERTICAL JUMP

EQUIPMENT
- Roll of paper, tape to secure paper to wall and mark each jump, 0.5 cm, tape measure, chair or table

SET-UP
Secure a 0.5 cm, roll of tape to a wall using tape. Place an additional piece of tape evenly 0.5 cm from the wall.

ASSESSMENT OBJECTIVE
- Recorded height for each jump
- Record the number of successful jumps
- Record the highest jump of three trials

ASSESSMENT PROTOCOL
1. Place the athlete's feet flat on the ground with knees slightly bent.
2. The athlete stands on one leg, with the foot flat on the ground, and jumps as high as possible.
3. The athlete lands on the same foot, with the foot flat on the ground, and jumps as high as possible.
4. The athlete repeats the jump three times.

SINGLE LEG BOUND LEFT

EQUIPMENT
- 1.7 m pole, measuring tape, short, flat on the floor

SET-UP
Secure the pole to the floor using tape, leaving a distance of 1.5 m between the pole and the floor. The athlete stands on the pole with one leg and jumps with the other leg.

ASSESSMENT OBJECTIVE
- Recorded time for one trial
- Recorded the number of successful jumps
- Recorded the longest distance of two successful jumps

ASSESSMENT PROTOCOL
1. The athlete picks up the pole with both hands and stands on the pole with one leg.
2. The athlete jumps with the pole and lands on the pole with the other leg.
3. The athlete jumps with the pole and lands on the pole with the other leg.
4. The athlete repeats the jump three times.

TIME TUCK JUMPS

EQUIPMENT
- 1.7 m pole, measuring tape, short, flat on the floor

SET-UP
Lay a pole on the floor, secure the pole to the floor using tape, according to the athlete's hip or leg height.

ASSESSMENT OBJECTIVE
- Recorded time for one trial
- Recorded the number of successful jumps
- Recorded the longest distance of two successful jumps

ASSESSMENT PROTOCOL
1. The athlete picks up the pole with both hands and stands on the pole with one leg.
2. The athlete jumps with the pole and lands on the pole with the other leg.
3. The athlete jumps with the pole and lands on the pole with the other leg.
4. The athlete repeats the jump three times.

Incomplete jump

Incomplete jump

Incomplete jump
PUSH-UPS

EQUIPMENT
- Medicine ball, 45° slide mat, yoga mat (optional)

SET-UP
- Have the athlete sit on 60° foam and positioned close enough so the athlete and assessor can clearly hear the test.

ASSESSMENT OBJECTIVE
- Count
- Complete as many push-ups as possible while maintaining contact with the medicine ball and proper body position.
- Record the number of successful repetitions.

ASSESSMENT PROTOCOL
1. Perform push-ups with both feet on the medicine ball. The knees are bent to 90 degrees, while maintaining full body contact with the medicine ball.
2. Count the number of push-ups the athlete is able to perform without losing contact with the medicine ball.
3. Allow the athlete to rest and proceed to the next position or continue with the test.

BENT KNEE V-UP

EQUIPMENT
- Yoga mat, stretch bands

SET-UP
- Place the athlete in a supine position on the mat, with the knees extended and the feet gently supporting the floor while the arms extended behind the head.

ASSESSMENT OBJECTIVE
- Count
- Measure in 10-second intervals as possible in 30 seconds.
- Determine the number of successful repetitions completed in 30 seconds.
- Check to see if there is an additional repetition.

ASSESSMENT PROTOCOL
1. Place the athlete in a supine position on the mat, with the knees extended and the feet gently supporting the floor while the arms extended behind the head.
2. Count the number of successful repetitions completed in 30 seconds.
3. Allow the athlete to rest, and record the number of successful repetitions completed in 30 seconds.
4. Count the number of additional repetitions completed in 30 seconds.

SIDE PLANK

EQUIPMENT
- Yoga mat, 45° slide mat, 45° slide tape measure, two 45° slide tape measure blocks, duct/elastic tape

SET-UP
- Secure 45° slide tape measure to a wall using either duct tape or painter's tape. Place 45° slide tape measure blocks behind the athlete on the floor.

ASSESSMENT OBJECTIVE
- To maintain plank position for maximum amount of time.
- Record time to second, thousandth.
- Maximum time of 60 seconds.
- Record the time during each test.
- If there is an additional repetition, adjust or evaluate for time.

ASSESSMENT PROTOCOL
1. Have an athlete lay on his/her side with bent knees and bent elbows above the head. The athlete on the grounded side foot is on the floor with the other knee tucked up under the body. The athlete is then facing away from the assessor.
2. Have the athlete maintain the plank position by lifting the upper body and extending the arms to a straight line, with supporting shoulder directly over supporting elbow. The feet and shoulders should be in line, with a 90-degree angle at the hip and elbow.
3. Hold the position for 30 seconds.
4. If the athlete is unable to maintain the plank position, the test is ended.
5. Record the total time for each test.

FRONT SPLIT

EQUIPMENT
- 12'/360° tape measure, 30" tape measure, 12" ruler, calculator

SET-UP
- Measure the athlete's upper body using the following criteria:
- Length is to the nearest 1/2" (0.5 cm).
- Record the data in the following table.

ASSESSMENT OBJECTIVE
- To demonstrate a split position to the best of the athlete's ability.
- Distance
- Measurements to be recorded to 1/2" (0.5 cm).
- For purposes of assessing the distance, the split is defined as the distance from the center of the foot to the nearest point of contact with the floor.

ASSESSMENT PROTOCOL
1. Athlete stands parallel to the measuring tape. Using hands for balance, the athlete extends her feet and bends her legs in a split position. The athlete then does the same with her other leg.
2. The athlete demonstrates a full split position with her feet parallel and feet off the ground. The athlete is encouraged to perform the split as many times as possible.
3. The athlete is not in contact with the floor and cannot reach the floor for balance, nor is he or she the athlete in the split position.
4. Record the measurement of the split.
5. The athlete is in contact with the floor and can reach the floor for balance, nor is he or she the athlete in the split position.
6. Record the measurement of the split.
7. The athlete is not in contact with the floor and cannot reach the floor for balance, nor is he or she the athlete in the split position.
8. Record the measurement of the split.
9. The athlete is in contact with the floor and can reach the floor for balance, nor is he or she the athlete in the split position.
STANDING SPIRAL

EQUIPMENT
- 20" tape measure

SET-UP
Place the athlete seated on a wall or table so he or she is seated and standing on the floor with his or her heels flat and the hands flat on the floor. The athlete should be positioned in the seated position with the knees extended and the feet flat on the floor. The two feet should be approximately 6 inches apart. The tape measure should be placed on the floor and the athlete's ankle. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.

ASSESSMENT OBJECTIVE
- To measure the distance of the athlete's spiral position
- To assess the athlete's ability to control the distance of the spiral position

ASSESSMENT PROTOCOL
1. The athlete sits on the floor with the feet flat on the floor and the knees extended. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
2. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
3. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
4. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
5. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.

SEATED REACH

EQUIPMENT
- 20" tape measure

SET-UP
Use the 20" tape measure to the floor, place a chair or the back of a chair 20" away from the wall and ask the athlete to stand on the floor with both feet flat on the floor. The athlete should be seated on the floor with the legs extended. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.

ASSESSMENT OBJECTIVE
- To measure the distance of the athlete's seated reach
- To assess the athlete's ability to control the distance of the seated reach

ASSESSMENT PROTOCOL
1. The athlete sits on the floor with the feet flat on the floor and the knees extended. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
2. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
3. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
4. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
5. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.

LUMBAR EXTENSION

EQUIPMENT
- Tape measure

SET-UP
No set-up necessary for equipment

ASSESSMENT OBJECTIVE
- To measure the athlete's lumbar extension
- To assess the athlete's ability to control the athlete's lumbar extension

ASSESSMENT PROTOCOL
1. The athlete is seated on the floor with the feet flat on the floor and the knees extended. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
2. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
3. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
4. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
5. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.

SPIRAL BALANCE

EQUIPMENT
- 8" x 10" trial balance

SET-UP
In an open area, place the trial balance on the floor with the feet flat on the floor and the knees extended. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.

ASSESSMENT OBJECTIVE
- To measure the athlete's balance on the trial balance
- To assess the athlete's ability to control the athlete's balance on the trial balance

ASSESSMENT PROTOCOL
1. The athlete is seated on the floor with the feet flat on the floor and the knees extended. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
2. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
3. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
4. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
5. The athlete's feet should be approximately 6 inches apart. The athlete's arms should be relaxed and hanging by their sides. The athlete should be seated in a relaxed position with the legs extended. The athlete's feet should be flat on the floor. The athlete's arms should be relaxed and hanging by their sides.
ANTHROPOMETRIC MEASUREMENTS

TORSO CIRCUMFERENCE
1. Achieve stands on both feet with feet hip-width apart.
2. Back that you are going to "reach" your hands outward to the sides.
3. Using a tape measure, make sure that your hands are touch
   4. Place your right hand on the right side of the body and your
   5. Place your left hand on the left side of the body and your
   6. Measure distance from widest part of waist to widest part of
   7. Measure distance from widest part of thigh to widest part of

REFERENCES
Appendix E. High Performance Movement Screen

HPMS INTRODUCTION

The purpose of the movement screen designed by the United States Olympic High Performance Department is to assess movement patterns in figures skaters to identify and treat mechanisms that may prohibit optimal performance. Physical performance has the highest risk of career injury in the lower extremity as well as the upper extremity and head injuries. Knowledge of the high performance movement screen as valid and reliable tools to assess mobility and stability in the lower extremity as well as balance is key for conclusion. These tools indicate the balanced test, single leg squat, rotatory squat, shoulder mobility, hip mobility, and the balance error scoring system. It is important to note that the goal of the movement screen is not to predict injury. Rather, the goal is to minimize risk of injury and maximize performance.

HIGH PERFORMANCE MOVEMENT SCREEN OBJECTIVES

1. Evaluate stability, mobility, and symmetry through evidence-based assessments.
2. Score the athlete accurately to create a load stimulus.
3. Provide a progression to meeting and corrective exercises to increase stability, mobility, and symmetric.
4. Communicate the needs of the athlete to the coach.

STRUCTURE/SET-UP

The high-performance movement screen is administered by a physician, physical therapist, or certified athletic trainer that has experience in movement screens and has been trained by the U.S. Olympic Sports Science and Medicine staff. The screen is a one-on-one evaluation that takes approximately 30 minutes to complete. The assessment moves through the evaluations with the test items being scored in a predetermined order. The screen provides notes/feedback on the athlete's score sheet.

1. Y Balance Assessment
2. T Balance Assessment
3. Tape measure
4. Hops test with two parallel pieces of costant tape either 1 or 2 in. apart
5. Axle test
6. V-sit
7. Clamshell

ATHLETE SCREEN AND PREPARE

The test will consist of feedback in the categories of balance, mobility, stability, and movement. Each assessment will correspond with a colored flag green, yellow, red, and blue. A green flag indicates that the athlete completed the movement screen on both the right and left side with good form and no deviations. A yellow flag indicates some deviations in the test, and a red flag indicates a trend with a decreased score or a deviation that requires further attention. A blue flag indicates a trend with an increased score or a deviation that requires further attention. An online link is specific to each athlete. Assessors will also have the opportunity to provide additional feedback or recommendations for the particular athlete's needs.

The assessors will receive feedback in the categories of balance, mobility, stability, and movement. Each assessment will correspond with a colored flag green, yellow, red, and blue. A green flag indicates that the athlete completed the movement screen on both the right and left side with good form and no deviations. A yellow flag indicates some deviations in the test, and a red flag indicates a trend with a decreased score or a deviation that requires further attention. A blue flag indicates a trend with an increased score or a deviation that requires further attention. An online link is specific to each athlete. Assessors will also have the opportunity to provide additional feedback or recommendations for the particular athlete's needs.

Equipment:

- Y Balance Apparatus
- T Balance Apparatus
- Tape measure

Set-Up:

- The tester will use a balance beam for the assessment. They will have an opportunity to practice the test is each direction prior to the assessment.

Assessment:

- The tester will begin standing with their leg over the beam to the Y Balance apparatus.
- The tester will complete the assessment with both hands placed on the beam.
- The tester will begin standing with their leg over the beam to the T Balance apparatus.
- The tester will complete the assessment with both hands placed on the beam.
- The tester will complete the assessment with both hands placed on the beam.

Measurement and Scoring:

- Each trial will be recorded on the score sheet.
- The tester will record the recorded whole number. If the tester does not see the score, record the total score.
- The average of each direction will be calculated in the athlete's name.
**SINGLE LEG SQUAT**

**EQUIPMENT**
- No equipment necessary.

**SETUP**
- Skater will stand on one foot, with both hands on hips and eyes focused straight ahead.
- Place a straight edge or a piece of cardboard at the hip width distance from the wall.
- Place the straight edge or cardboard on the floor, approximately 2 inches wide and 20 inches long.

**ASSESSMENT**
- Hold the skater squat in a comfortable level and return to the starting position.
- The skater will perform five minutes of squats.
- The top leg should remain stationary to the starting leg and will not move beneath the crouching feet.
- Observe the skater’s knees, back, and searching behavior.

**MEASUREMENT AND SCORING**
- All repetitions must be executed with the same knee, left or right.
- The skater will stand on the same foot and lift the other leg.
- Record the number of times executed.

**SHOULDER MOBILITY ASSESSMENT**

**EQUIPMENT**
- Tape measure.

**SETUP**
- Place the skater on one side of the room, with the opposite leg on a block.
- Place the skater on a block and measure the distance from the block to the floor.

**ASSESSMENT**
- Grasp the skater’s hand and pull it towards the floor.
- Observe the skater’s arm positioning.
- Measure the distance between the block and the floor.

**MEASUREMENT AND SCORING**
- The skater should maintain the same elevation throughout.
- Record the distance in centimeters.

**ROTORARY STABILITY**

**EQUIPMENT**
- Yoga mat with two spots of tape exactly 6" apart.

**SET-UP**
- Skater stands on the yoga mat, with one foot on the tape and the other foot on the floor.
- Skater will perform five minutes of squats.

**ASSESSMENT**
- Observe the skater’s ability to maintain balance.
- Observe the skater’s ability to maintain balance.

**MEASUREMENT AND SCORING**
- Observe the skater’s ability to maintain balance.
- Record the duration of time spent in each position.

**BALANCE ERROR SCORING SYSTEM**

**EQUIPMENT**
- Yoga mat, two spots.

**SET-UP**
- Skater will perform in three different trials on two different spots.
- Skater will perform in three different trials on two different spots.

**ASSESSMENT**
- Observe the skater’s ability to maintain balance.
- Observe the skater’s ability to maintain balance.

**MEASUREMENT AND SCORING**
- Observe the skater’s ability to maintain balance.
- Record the duration of time spent in each position.

**REMARKS:**
- Include all of the following:
  - Pacing, eye contact, arm raises.
  - Observe for changes in the skater’s performance.
HPMS REFERENCES

Appendix F. Supplemental videos

**Video F1:** https://www.youtube.com/watch?v=hzQOu7bRE&list=PL-CheZaoFWwQtDam8Fv62p_lqRHvai0ST&t=1s

**Video F2:**
https://www.facebook.com/433625946686191/videos/699678550857559

**Video F3:**
https://www.youtube.com/watch?v=FLvS-oQLeaw&list=PL7Kmj40VqIOqPfIRkTwcbyafbq_GfXNrz

**Video F4:**
https://www.youtube.com/watch?v=_dRwJiYjBzw&list=PL7Kmj40VqIOOy7Thm9h3V4BojIn2FCyof
Appendix H. Functional Movement Screen
Retrieved from: https://www.simonjarvismovementspecialist.com/movementtests