BUILDING A SUCCESSFUL RELATIONSHIP: SPORT SCIENCE SERVICES FOR U.S. DIVING

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INTRODUCTION: Applied biomechanists must often cross the bridge from science to practice. Practitioners and scientists should work together in a seamless and supportive manner. Many models for integrating sport science services into high-performance sport have been used, with varying results (Benton, 2003; Wang, 2005). In the United States, the sport of diving has included science in its high-performance programs for more than 25 years, using a variety of models (McLaughlin, 2007). Initially, sport science was integrated into the performance program as a budget item, offering funding to proposals put forth from specific sport science and medicine disciplines, typically from University academics. An annual sport science and technology conference was funded and served as the primary means by which research findings were provided to coaches. In 2002, USA Diving adopted an interdisciplinary approach of sport science and sports medicine services in the continuing quest for podium finishes. A Performance Enhancement Team (PET) was created which included specialists in nutrition, physiology, biomechanics, medicine, and psychology. Interaction with coaches and athletes occurred primarily at bi-annual training camps, and included educational presentations, data collection and assessment, and individual feedback to athletes and coaches from the PET. Following the 2008 Olympics, the PET and its organizational tenets were dissolved. A new high performance director was hired, bringing a fresh view of diving excellence and a reduced attention to sport science and medicine services.

In the London Games, USA diving won its first Olympic medals in 12 years (n = 4), including our first medals in the synchronized events. This paper will discuss the author's experiences as a contributor to sport science services with USA Diving during the past 20 years, present research and service successes and challenges, and suggest tactics for future sport science practitioners integrating their services with sport national governing bodies.

PHYSICAL & TECHNICAL DEMANDS OF DIVING: Diving is a sport of precision and consistency. Athlete preparation arises from five domains; physical (strength, power, flexibility, nutrition, etc.), technical (skill, technique, biomechanics, etc.), tactical (strategy in dive selection, order, difficulty), psychological (relaxation, concentration, imagery, ritualization, etc.), and logistical (competition selection, periodization, etc.). Biomechanics and technique have dominated the discourse, research, and coaching attention in diving (Köthe, 2013). However, recent years have shown that the physical preparation of divers may be the key component that discriminates the champions from the rest. Divers must launch themselves into the air from a surface, making jumping ability critical, although at the highest levels basic jump tests may not distinguish the best athletes from the rest of the field (Sands, McNeal, & Shultz, 1999). The jumping environment of diving is not the same as that seen in other sports however. Divers propel their bodies in varying directions as a result of the jump, and may even 'jump' from their hands. Contact times and durations of force application tend to be longer (upwards of 750 ms; Miller, 1983; Miller, 2000) than seen in other jumping activities such as track and field jumps. As duration of force application increases, the contribution of maximal strength also increases (Schmidtbleicher, 1992; 2002). Thus, maximal strength of the lower extremity is an important physical ability for successful divers (McNeal, 2007, 2013; O'Brien, 1992, 1993). Additionally, aerial somersaulting requires the ability to shorten the body from an elongated position while maintaining a precise alignment (King & Yeadon, 2003; Yeadon, 1997). Power production of the trunk muscles is therefore critical for initiating the somersault action and in preparation for water entry. Exquisitely coordinated whole-body range-of-motion (ROM) is important for two reasons: 1) aesthetics of skill execution and 2) effective biomechanics. The rapid and complex movements of diving require dynamic, coordinated ROM (McNeal & Sands, 2006). Dynamic ROM training is preceded by fundamental static ROM positions, and as such, dynamic ROM is built from maximal static ROM. Strength, power, and ROM, must be coordinated to achieve ideal positions at ideal times and in the correct sequences (Slobounov & Newell, 1996). However, the crucial qualities of strength, power, ROM, and alignment are merely abstract until one is able to test them. Testing and monitoring these abilities was a vital starting point for the author's sport science service integration with USA Diving.

TESTING AND MONITORING: Performance testing programs are important components in the development of high-performance athletes (Mason, 2000; Pyke, 2000; Sands & Stone, 2006a, 2006b). A testing program must assess talent, preparation status, and all relevant components of diving-specific fitness. While testing is a simple idea, implementation is wrought with complexities. Tests must be valid, reliable, and feasible with regard to access to athletes, equipment availability, expertise, time limitations, analysis, feedback, and cost (Gore, 2000; Sands, 2008). Developing and implementing a physical abilities testing program that was feasible and specific for diving was one of the primary tasks of the author. The program was designed and refined over the course of eight years. The following sections present selected examples of the evolution of the physical abilities test program for USA Diving and its impact on training practices (McNeal, 2007, 2013).

MAXIMAL STRENGTH: Historically, US divers had been successful by simply 'diving into shape.' Despite evidence suggesting the important role of lower extremity strength in diving performance (Miller & Munro, 1984), maximal strength training and testing was not embraced by coaches and athletes. The initial physical testing program included a traditional five repetition-maximum back squat exercise to assess maximal strength. Unfortunately, it was immediately apparent that this was not feasible because few athletes actually performed heavy back squats in training. Moreover, coaches and athletes shared concerns about injury associated with heavy squats in spite of nothing further than anecdotal evidence (Lloyd et al., 2012). Athletes also feared 'bulking up.' A leg press was not feasible because of equipment requirements and the need for testing at many centers across the country. As a result, testing for maximal strength of the lower extremity was abandoned for several years.

In the quadrennium leading to the 2012 Olympic Games, a new approach was attempted. Feasibility issues were addressed, strength training education ensued, and information from conditioning programs in other countries rekindled the need for more advanced forms of training. Leading to 2012, maximal strength testing of the lower extremity was re-introduced using a single, maximal effort, isometric back squat performed in a traditional squat 'cage' against an immoveable resistance. The athletes did this while standing on a portable force platform. Average maximal force (50ms) exerted during a three-second effort was calculated and reported relative to athlete body weight. Results from this test were later shown to be the single biggest physical ability predictor of Olympic team membership vs non-membership for the 2012 Olympic Games (McNeal, 2013). Also during this quadrennium, visits to individual athletes' training sites allowed the author close and individual contact with the athletes, coaches, and local service providers. Furthermore, the trust built from these interactions helped to establish confidence in the methodologies and training programs utilized, including those for developing and testing lower body maximal strength.

POWER: Power expression is obvious in diving jumps. However, more subtle aspects of power are equally important. The diver must be able to sustain large muscle tensions during the countermovement phase of jumps and while 'loading' the springboard. Initial jump testing involved the performance of reactive drop jumps, counter-movement jumps, and concentric squat jumps from a portable force platform. For many years the author reported to the coaches and athletes multiple variables related to jump performance obtained from force-time records. Coaches and athletes had difficulty comprehending this information, in particular how it related to training strategy. Simple correlation analysis of the force-time variables, supported by published findings (Markstrom & Olsson, 2013; Young, Cormack, Crichton, 2011), determined that jump height and peak force best distinguished divers of differing abilities in this population. These variables were understandable by the coaches, and easily reported in normative tables. During the years where maximal squat testing was abandoned, dumbbell weight (50% body weight) was added to the concentric squat jump in order to obtain a power measure that relied to a greater degree on maximal strength (Stone, et al., 2003). This information, combined with the other jump performances, allowed the author to direct coaches to emphasize specific types of strength or power training for a particular athlete (Marina, Jemni, Rodríguez, 2013).

Power is also expressed during somersaulting and twisting, as the diver moves to and from extreme positions quickly. An initial testing program included video recording and digitizing of a land-based standing back somersault, performed 'free' without the use of the hands to grab the legs. Data reported were height of rise of center-of-mass, and rate of closure into the tuck position. This test was abandoned when it was found not to be feasible in performing a quick turnaround of results to the coaches and athletes. In its place, a modified version of hanging pike-ups (Sands, 1993) was used to evaluate trunk power. This test clearly distinguished athletes of differing levels, and identified not only power weaknesses but also flexibility issues associated with achieving a maximal pike position actively. As a result of this testing, an increased emphasis on land somersaults and the inclusion of weighted somersaults was encouraged. Weighted somersaulting was particularly helpful, and has been an important addition to physical training programs. Analysis of the acute effects of weighted somersaults showed the optimal vest weight to maximize height of rise of the COM and rate of closure into the somersault (McNeal & Martin, 2008). The ever-increasing degree of difficulty requirements will continue to tax jumping and trunk power abilities, and further research into the evaluation and training of these qualities is needed.

RANGE OF MOTION: Divers must achieve extreme ROMs during competition and training. Hip, spine, and calf ROM are directly related to performance and require intense training and assessment. The 'Biggs' splits test was implemented to assess passive, static ROM in hip flexion and hyperextension (Sands, McNeal, Stone, Russell, & Jemni, 2006). Manual digitizing of anatomical landmarks of the pelvis and lower limbs generated degree-of-split values. Given the relative importance of active ROM in performing diving skills, a seated single-leg-lift was also included in the test program. From these two measures of active and passive hip ROM, a ratio was created to represent the concept of 'flexibility deficit', as suggested by (Siff & Verkhoshansky, 1996). Training recommendations, in particular for active ROM development were provided to coaches. Further research is merited to evaluate the validity of the flexibility deficit, determine the effectiveness of training interventions, and the deficit's potential relationship to injury and performance of diving-specific skills.

Building from work at the U.S. Olympic Training Center (McNeal & Sands, 2006; Sands & McNeal, 2013), vibration stretching was applied to encourage passive ROM development. Impressive results were especially noted when vibration training was continued through periods of significant growth in limb lengths in some athletes. Future research and service efforts will be directed toward improving our understanding of the role of shoulder flexibility and its relation to injury incidence as well as its role in the execution of diving skills (Rubin, 1999).

CONCLUSION & RECOMMENDATIONS: The future of USA Diving will undoubtedly be tied to the incorporation of cutting-edge strength, power, and flexibility training and evaluation methods. The rise of the synchronized diving event will be addressed using paired force platforms to assess synchronized jumping. In addition, the physical preparation of divers will merge with skill training through the incorporation of alignment characteristics and dive-specific fitness. Body alignment is crucial for effective transfer of jumping and springboard forces and aesthetics. Current research is addressing the concept of straight-body alignment, and determining aspects most related to performance, which traits may be trainable and those which should be selected for.

Based on the author's experiences in supporting the training and performance needs of USA Diving athletes, current and future sport science practitioners should be encouraged to 1) develop a coaching background through hands-on involvement including interning or job shadowing, 2) create a multilateral approach to their academic education, including coursework in all sport science areas, 3) develop a team mentality and study team and leadership literature, especially the concept of servant leadership, 4) interact with other sports disciplines through regular review of coaching websites and publications, conferences of other NGBs and from other sport science disciplines.

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