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A Case Study of Technical Change and Rehabilitation: Intervention Design and Interdisciplinary Team Interaction

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Suggested Running Head: TECHNICAL CHANGE AND REHABILITATION INTERVENTION

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Abstract

The design of effective interventions in sport psychology often requires a subtle blend of techniques, tailored to meet the client's specific needs. Input from a variety of disciplinary support specialists, working as a team, is also frequently needed. Accordingly, this study investigated an interdisciplinary team approach to the technical change and rehabilitation of an elite weight lifter following injury; necessitating the avoidance of regression when performing under competitive pressure. Multiple coaching approaches were used and complimented by targeting specific mental skills. Kinematic analyses indicated progressive technical, and subsequently permanent, change even after 2 years. Self-report measures of self-efficacy and imagery use were deemed essential in facilitating the change. Finally, a discussion focuses on the intervention's multifactorial nature, its application within high performance coaching, and how this may advise future research into the refinement of already existing and well-established skills.

Keywords: skill refinement, pressure resistance, elite performer, motor imagery.

A Case Study of Technical Change and Rehabilitation: Intervention Design and Interdisciplinary Team Interaction

Athletic injury is an unfortunate but common reality in sport, especially when coupled with a strong desire to win under high competitive pressure; this reality is particularly apparent in elite-level weight lifting. Although there are many factors that may contribute to injury, for example inadequate warm-up behaviors (Woods, Bishop, & Jones, 2007) or under/overtraining (Baquie & Brukner, 1997), in many power-oriented sports, injury may often be attributed to poor movement execution (Hedrick & Wada, 2008). Accordingly, in circumstances where an athlete possess a well-established, and automatically controlled (i.e., subconsciously) technique (Fitts & Posner, 1967), but shows consistent movement error, the option of technical change can become a crucial consideration, both in the interest of safety and ensuring future competitive participation. Hence, understanding how to optimize this process should be of significant interest to both athlete and coach.

A major concern when changing technique in sports such as weight lifting is failure to change correctly *but also* securely (i.e., making change resistant to the effects of competitive pressure). In such cases, this failure can result in further chronic injury and a permanent absence from high-level participation. This scenario presents a serious problem when working with elite athletes, since their habitual tendencies have been shown to be robust under conventional coaching instruction (Jenkins, 2008), making technical regression a distinct possibility (cf. MacPherson, Turner, & Collins, 2007). From a psychological perspective, additional complexity comes when the change required is associated with a current need for physical rehabilitation caused by injury (Podlog, Dimmock, & Miller, 2011). Clearly these circumstances present an even greater need for interdisciplinary consideration towards training design, most obviously from physiotherapy, motor control, and sport psychology perspectives.

Addressing this scenario, technical change interventions must be implemented both deliberately and sensitively within the rehabilitation process; adopting a perspective of extended psychological compared to physical rehabilitation. Magyar and Duda (2000) support this suggestion, finding that injured athletes receive their greatest source of confidence from their initial judgments of the rehabilitation setting and when perceptions of coach leadership and social support are high. These findings also clearly substantiate the need for interdisciplinary teams. Importantly however, is the scope of holistic contribution that may be provided by the sport psychologist—utilizing a *package* approach of several complimentary techniques in combination to bring about technical change and, subsequent security to competitive pressure (cf. Martindale & Collins, 2012).

Consequently, this paper describes an exemplar intervention strategy used to refine the technique, self-perceptions, and performance of an injured elite weight lifter. The multifactorial nature of the intervention and intent to bring about change correctly and securely is particularly emphasized. Furthermore, the paper offers an insight into the use of an interdisciplinary team, addressing questions concerning some theoretical research and its application for performance enhancement. However, before explaining the theoretical perspectives underlying the intervention, a description of the problem will be provided.

The Athlete and Focus for the Intervention

The athlete in question, “J,” was a male, elite Olympic weight lifter, at the time in transition from the National junior to senior squad. In attempting to qualify for the Commonwealth Games, which were to be held in August, the athlete was required to compete at the British Championships in June of the same year. It was following these championships that the coaches and sport psychologist decided to intervene; the issue being forced by injury, brought on by a long-term technical fault. This was coupled with the need to be fit, and technically safe, for the Commonwealth Games only 10 weeks away.

The incident occurred during the first phase of the competition, the two hand snatch. In this lift, “the bar shall be placed horizontally in front of the lifter’s legs. It is gripped, palms downwards and pulled in a single movement from the platform to the full extent of both arms above the head” (Hartfield, 1994, p. 53). Although athlete J performed one legal snatch of 105 kg, he received a Grade 2 sprain to the ulna collateral ligament of the right elbow, which was verified by the team doctor and later by the team physiotherapist. From film of the event, the coaches identified, subjectively and independently, that the technique was “flawed” and probably led to the injury. Furthermore, they confirmed to the sport psychologist and physiotherapist that this flawed technique was a common feature of this athlete’s lifting, and that coaches had previously attempted to rectify this using contemporary corrective coaching procedure (i.e., their normal repertoire of coaching “tools”).

Injury and Technical Evaluation

During training it was common practice for the sport psychologist to film the lifters from the sagittal plane (side on). Two-dimensional analyses were regularly undertaken of important lifts. In addition, during the British Championships, we performed a three-dimensional analysis of the lifters (see method section). From these two sources, we were able to obtain information concerning the angular displacements of the right arm complex. These data proved invaluable in verifying the opinions of the coaches and providing support pertaining to the etiology of the injury; findings which were independently assessed by the team doctor and physiotherapist. Data also provided the team with two important facts about the case. Firstly, the technique employed by athlete J was consistent. These data demonstrated that the lifter was executing a similar movement strategy both during and prior to the injury (Figure 1). Secondly, the cause of the injury was determined. Through the application of both kinematic data and conventional diagnostic procedures, it was suggested that the injury was caused by valgus strain (functional abduction) of the right elbow joint.

This movement is normally inhibited by the ulna collateral ligament. The athlete had been aware of this problem for some time; however, the combination of the weight attempted plus flawed technique resulted in a partial rupture of the ligament. Despite his appropriate concerns, prior to the intervention, the athlete had been unable to complete the technical change indicated by both data and coaches.

Based on the case history, the following aims for the intervention were determined; to (a) rehabilitate the injury through contemporary clinical practice, (b) correct the technique in order to minimize further injury potential, and (c) improve athlete J's mental and physical readiness for the Commonwealth Games, 10 weeks away.

Theoretical Rationale for the Intervention

Flaws in technique. "Bad habits" or *systematic behavioral biases*, may be caused by a variety of different mechanisms, including, as a direct result of progressive incorrect skill acquisition (Walter & Swinnen, 1994). Thus, errors in performance appear to be able to "creep up" on the best of athletes. Furthermore, many coaches and some psychologists have highlighted that, if an athlete becomes too experienced in a particular movement pattern, there is little possibility of technical change over a short period of time (see Hanin, Korjus, Jouste, & Baxter, 2002). Indeed, it has been shown that at this stage of motor learning, such movement techniques have been automated (controlled subconsciously) and are therefore highly resistant to change when using conventional coaching practice (Maschette, 1985, cited in Hanin et al., 2002) or unaided by external guidance (cf. MacPherson et al., 2007). More optimistically however, a review by Walter and Swinnen (1994) suggested that, "some performers may have particular difficulty in dissolving 'bad habits' that have emerged early in learning. These individuals may especially benefit from training strategies that are specifically designed to help the individual depart from their preferred movement pattern" (p.

509). There is, therefore, a highlighted need to further investigate the refinement of technique in such individuals.

From a motor control perspective, laboratory-based research could be used to inform this departure process. Findings have shown that the stability of a to-be-learned movement over time is dependent on its proximity to the already well-established (i.e., stable) movement pattern (Kostrubiec, Tallet, & Zanone, 2006). In summary, the greater the distinction between these two movement patterns, the more persistent the new memory trace will be. By contrast, more similar to-be-learned movements demonstrate initially higher levels of accuracy, but weaker characteristics in terms of long-term stability; suggesting that movements which are similar to the already well-established technique, may be harder to permanently stabilize. Certainly coaches report this to be the case in athletics field events (Trower, 1996), which is of particular concern when a time constraint is placed upon the intervention, as in this case of elite weight lifting. Crucially however, the findings of Kostrubiec and colleagues run contrary to the suggestion of maintaining "automization" over the existing technique, representing a *continuously* implicit level of control (Rendell, Farrow, Masters, & Plummer, 2011), while undergoing technical change. Automization, which characterizes well-learned and pressure resistant skills at high-levels of performance, must be initially "deautomated" (cf. Beilock, Bertenthal, McCoy, & Carr, 2004; Oudejans, Koedijker, & Beek, 2007). In fact, several applied studies have already exploited the movement deautomation process by introducing *contrast training* as a means of generating this necessary and conscious distinction (see Collins, Morriss, & Trower, 1999; Hanin et al., 2002), before reautomating the technique under conditions of lower conscious control (i.e., change as a nonlinear process). Notably, however, despite the fact that contrast drills are an established and clearly useful element of the change process, scarce data exists on the potential optimization of effects when undertaking a technical change intervention, and the inherent challenges with this process, through the complementary use of effective mental skills. Such skills as imagery (Winter & Collins, 2013), observational learning (Ashford, Bennett, & Davids, 2006), and being able to realistically evaluate performance (MacNamara, Holmes, & Collins, 2008) are all valuable skills in enhancing the potential for skill development. Accordingly, it was a key goal for the coaching team, including the sport psychologist, to provide appropriate training in mental skill development as well as providing the athlete with a prognosis to the technical flaw.

Imagery and observational learning. The most predominant intervention technique used by sport psychologists to overcome skill disorders is imagery, or mental practice (Morris, Spittle, & Watt, 2005). This technique initially requires the covert formulation of a physically practiced behavior. The behavior is then manipulated or reinforced, often by means of verbal propositions from the psychologist. However, the generation of images through verbal proposition can be arduous, particularly if the individual is not well practiced at the target behavior, or unsure of the exact demands placed upon them. To support these individuals, one tool which can be used to generate vivid and controllable images is observational learning. Rushall (1988) defined the observational learning procedure as “the learning of new behaviors or the altering of existing behaviors by imagining scenes of others interacting with the environment” (p. 132).

A number of theories have been proposed to explain the observation–behavior relationship. Probably, the most complete attempt was forwarded by Bandura (1977, 1986), who proposed that observation is one of the primary modes used by individuals to develop cognitive skills. Bandura explained that symbolic representation, or verbal coding, takes place when one views a particular model. This representation is then used as a referent for the establishment of a new behavioral pattern. Further support for this notion exists from Lang’s (1979) bioinformational theory, which relates to a cerebral structure of associated neural networks, or cell assemblies. Each network is formed, based upon the information from the environment (intrinsic and extrinsic stimulus propositions) and semantic elaboration (meaning propositions) of the information encoded in memory. These networks are linked to encoded information about responding, using both somatomotor and autonomic nervous systems (response propositions). Inputs or cues that match concepts represented by the associative networks serve to activate that particular network. Given a sufficient number of matches between the perceptual information and that encoded within memory, the entire network is activated and processed as a unit, based upon the response information linked to that cue (cf. Smith, Holmes, Whitemore, & Devonport, 2001). From this, it would seem logical to expect that a strong perception–action link will exist between the environmental cues and the subsequent action and, therefore, likely to be more facilitative with elite athletes (McCullagh, Weiss, & Ross, 1989); a possible reason being that an elite athlete will have had prolonged exposure to stimulus, response, and meaning propositions. In summary, both observational learning and imagery strengthen or weaken associations between environmental cues and responses, thereby changing or reinforcing the associated neural network. The result is a modification or consolidation in the behavior.

Imagery interventions usually take the form of an imagery script which is, at least initially, read to the athlete. Observational learning, by contrast, takes the form of live or video demonstrations. Unlike an imagery script, where the information has been refined to produce a controllable and vivid image, a video demonstration contains task irrelevant, as well as task relevant information. Researchers have consequently argued that model characteristics affect other relevant processes, such as the attentional capacity of the observer. For example, McCullagh (1986) showed that individuals who observed a model with a perceived high-status level performed better on a Bachman ladder test than individuals who observed a low-status model. Accordingly, it seems essential that the model contains the characteristics which are considered to produce an optimal rate of technical change.

A prevalent debate exists regarding the optimal type of model used in the observational learning process (see Ste-Marie et al., 2012, for a review). For example, there are two types of model commonly under contention in the literature: the skilled “perfect” model, and the learning or coping model. By far the more popular of the two is the skilled model, whereby the observer watches a skilled performer complete the required movement pattern. It is argued that the skilled model demonstrates optimal characteristics of a particular movement pattern, thus providing the observer the opportunity to internalize a perfect technique in memory. This perceptual “blueprint” could then be compared to concurrent action and adjustments could be made as necessary. However, according to Lang’s theory (and subsequent empirical evidence from mirror neuron research; cf. Holmes & Calmals, 2011), there would be less association between the environmental information (the model) and the responses. In summary, it merely appears that a skilled model has evolved to be accepted as the norm, perhaps due to its ability to explicitly, and therefore more easily, highlight the stark contrasts between the learner’s and model technique.

This insistence on a perfect example is also in contrast to much of the skill acquisition literature. According to research into effective practice design, studies have found that, when a learner is administered a program that requires greater levels of mental processing during an acquisition period, improvements in outcome results are often delayed compared to when conditions are made easier (i.e., require lower mental processing). Interestingly however, employment of this practice design consistently leads to superior long-term retention and transfer. Examples of ways in which this effect can be achieved include, providing less frequent feedback, distributing practice sessions, and making the task more random in nature (Cross, Schmitt, & Grafton, 2007; Schmidt & Bjork, 1992). Neuroscientific theories explain this phenomenon through cortical reorganization increasing the capacity to resolve various stimuli (internal or external), therefore determining what is learned. By generating the conditions required to enhance the distinction between different stimuli this, in turn, results in a learned response associated with the multiple representations and a change in the neural networking (i.e., hard wiring; cf. Mercado, 2008). Thus, more effective behaviors are learned when presented with greater variation and inevitably error. Moreover, another important outcome concerns the learner being able to evaluate their own movement behaviors (Shadmehr, Smith, & Krakauer, 2010). Therefore, the use of a skilled model in the covert equivalent could potentially debilitate the individual's power of movement evaluation, quite apart from the impact on the subject's self-efficacy (Bandura, 1986).

For these reasons it is suggested that the use of a coping model to support mental practice may best facilitate the process of technical change. A coping model does demonstrate flaws in technique, however, if the flaws are similar to the observer's, then he or she can relate more closely (greater meaning propositions) to the model than if it were closer to perfection, in accordance with Lang (1979). The current research on coping versus expert models has produced equivocal findings (Ste-Marie et al., 2012). However, Ste-Marie et al. suggest that many studies are methodologically weak. Furthermore, we suggest that the cited research does not consider the confounding factors inherent in observational learning (observer characteristics and other model characteristics) when making a long-term technical change to an already well-established skill. Our technical change intervention is, therefore, derived from the theoretical propositions offered by Lang (1979) and Bandura (1977). While there have been mixed views on model type and technical change, the research on model type and self-efficacy seems to be more supportive of the use of coping models. Such models have been used to good effect in a variety of settings, such as social skills training (Kazdin, 1982). During injury, coping models have been reported to reduce the level of negative emotions and increase self-efficacy for the challenges of the rehabilitation process (e.g., Maddison, Prapavessis, & Clatworthy, 2006). As the proposed intervention utilized an injured performer this evidence supports the use of a coping model.

Reflecting these issues, the present intervention used a coping model as the demonstration to the athlete. Furthermore, the athlete himself was used as the model. According to Lang's bioinformational theory (1979), the covert image produced during mental imagery should be as close to the overt equivalent as possible. In such circumstances, a maximal match between the environmental cues and the representation in memory exists. The use of a self-model should logically allow a strong recall of associated behaviors and result in a more efficient process of technical change. This, in conjunction with showing adaptive behaviors inherent in a coping model, would lead to the generation of a "best self-model." Based on previous theoretical positions, this should maximize relevance and lead to enhanced self-efficacy while progressively adjusting the technical flaw. In practice, this requires the regular and progressive change in the model presented to demonstrate and "shape" the technique towards the target behavior (Figure 2).

Despite the mechanism proposed by Lang (1979), which can explain why self- and coping models are the most effective options, it could be argued that the combination of the two could be potentially detrimental to the athlete. If the two are combined, the individual will see their imperfect performance, which may have an inevitably detrimental effect upon self-efficacy. In this regard, Rushall (1988) initially instructed an athlete to visualize a complete stranger performing rather than the athlete himself in order to positively influence self-efficacy. However, this apparent contradiction in the literature may well be due to the "automatically negative" perception which is expected in response to error feedback. An individual will only perceive an error as negative if those errors are perceived as threatening to their performance enhancement (cf. Carron, 1988, on the effects of positive information based reward on intrinsic motivation), a common case when the changes needed are not known or seen as possible. If an accepted solution is provided in association with error feedback, however, the athlete knows what to do to improve, and is empowered to make the change. It would seem hard to imagine a negative response to this, so long as the performer felt that they were capable of effecting the desired change (hence the use of a self-model).

Intervention Design

In light of the above factors, to generate the optimum intervention design, we focused on these essential components:

- The athlete's technique had to change quickly, permanently, and be subsequently robust under pressure.
- From an imagery perspective, response propositions/kinesthetic consequences had to be maximized but also be accurate to the "new version" skill being refined.
- Self-efficacy throughout the process had to be high, thus progress had to be demonstrated to, and accepted by, the athlete.
- The whole process had to enhance but never inhibit the rehabilitation process.

At each stage, the lifter's own performance which best approximated the target behavior was used as the model for practice. Since the weight lifted is low (to avoid reinjury), the athlete can quickly generate a good approximation of the target technique, albeit that the movement feels extremely unnatural at first. This approach maximizes accurate "feel" for the new technique (the lifter has just executed what he sees, thus kinesthetic memory is high) and stresses the progress which has been made but always offers an achievable target behavior. Such feel is crucial to technical change, particularly in a sport like weight lifting (Lephart, Pincivero, Giraldo, & Fu, 1997). Boyce (1991) suggests that the "show and tell" paradigm of modeling is a minimalist rationale for motor performance enhancement. Of the possible modeling strategies, only self-modeling offers a clear reference to how the movement felt.

Method

Kinematic Data Collection

The use of kinematic data offered a highly objective evaluation of the intervention's efficacy. It also provided clear evidence to J that he had, indeed achieved the desired change. During the three-dimensional analyses, the specific technique employed subscribed to the Direct Linear Transformation method (DLT; Abdel-Aziz & Karara, 1971). This allowed relatively flexible placement of the cameras during filming, which can be a problem at competitive events. A Peak Performance (Peak Performance Technologies, Inc.) triaxial calibration structure was placed over the lifting area, encompassing the volume where the lifting would occur, just prior to the actual event. The two cameras were genlocked in order to synchronize the opening of the two camera shutters. Videos obtained from the two- and three-dimensional analyses were digitized using a software package developed and reported by Bartlett and Bowden (1993). During the two-dimensional analyses that took place during training, the camera was positioned perpendicular to the sagittal plane in order to measure the relative angle of the shoulder and elbow at the catch phase of the snatch lift.

After the British Championships, a retrospective kinematic analysis of the snatch lift was performed on five male weight lifters. This was to determine whether the deformation at the elbow observed in J was normal during such lifts. It was considered by the coaching staff that his movements were not normal.

Self-Perceptions

Throughout the intervention no formal questionnaires were administered to the athlete. The authors deemed it inappropriate to complicate or cloud the athlete's recovery with psychometric tests. Instead, the athlete reported on simple, almost self-designed scales, whether he was feeling good about his progress and confident that he would do well in the forthcoming Commonwealth Games. For example, a 10-point Likert scale was used to answer questions on the vividness and controllability of imagery (two questions) and the level of efficacy that the athlete would improve. In all cases, athlete J operationally defined what the numbers represented and knew what change looked like. The coach would ask him to rate his performance and provide a subjective description as to why he gave that score. This became a useful part of his goal setting. Furthermore, an additional, indirect indication of elevated efficacy was identified through the goals that he set for himself.

Support Team Dynamics

The support team consisted of two National coaches, one physiotherapist, one doctor, and two sport psychologists. The team would meet at least once a month during squad training. However, the person who made the final decisions pertaining to the intervention was athlete J, thus empowering him to take control of his own progress. Hence, while coaches provided the technical expertise, and the psychologists facilitated the technical change through instilling and developing mental skills, the athlete was the central figure during the intervention process. The physiotherapist and doctor rehabilitated the injury and issued consent to progress through the intervention.

The Intervention

The process was divided into five chronologically based stages:

Stage one (Weeks 0–2). During the first 2 weeks after the injury, athlete J received intense physiotherapy to reduce any inflammation and prevent the development of scar tissue forming around the ligament. With the consent of the physiotherapist and doctor, the psychologists and coaches intervened.

In practical sessions, the athlete assumed the receive position of the snatch, that is, he stood in a squat position with the bar above his head (the point where the injury was known to have taken place). He began by holding a broomstick handle above his head to ensure a reduced possibility of relapse. The position of the bar was manipulated in the sagittal plane by the coaches, while the athlete reported on how each position felt—generating a contrast in kinesthesia and realizing the change. After several manipulations, the athlete was asked to establish a series of self-generated cues for the different positions. For example, the athlete reported feeling his arms moving backwards once he had assumed the receive position. This process was important to establish awareness of the various positions.

Also, the athlete was encouraged to discuss the injury, and the reasons underlying it, with members of the support team. Previous discussion between the members of the support team meant that the athlete received a consistent message pertaining to the cause and the potential solution to the problem, and the future prognosis for his lifting.

Stage two (Weeks 2–4). By now, the athlete was able to lift a 20 kg Olympic bar. It was important to resume lifting the Olympic bar for two main reasons. Firstly, the use of a bar offered enhancement to the athlete's kinesthesia whilst representing his return to genuine lifting. Secondly, Zatsiorski (1995) stated that increased resistance will inevitably lead to increased recruitment, rate coding, and synchronization of motor units within the muscle fibers. If more motor units are activated, then there is a greater chance of kinesthetic feedback and awareness of contrast. Thus, the maximal weight allowed by the physiotherapist was attempted.

The athlete completed a series of repetitions, each consisting of a *correct* lift followed by an *incorrect* lift. This was to distinguish kinesthetic sensations between the two lifts. The emphasis was eventually placed upon the correct lifts by systematically fading out the incorrect lifts. This stage required the athlete to strengthen his ability to discriminate between, and evaluate the performances. During this stage, the athlete was asked to generate further cues regarding the kinesthesia which discriminated the good and bad lifts, thus developing a heightened kinesthetic awareness, and an increased acceptance and comfort with the new version. An example of an incorrect lift would be "increased tension in the chest," while a correct cue would be "weight on the balls of my feet."

Also, at this stage, J started to view his injurious performance on video, had the joint angle data and its significance explained, and was debriefed on the preparation (both training and precompetition) factors which he felt had led to it. By these means, understanding of the problem and solution were clarified and an action plan and a series of goals were developed. These provided J with a clear pathway to recovery, consisting of steps which he was confident he could achieve. The provision of a multifaceted plan, which included technical, psychological, therapeutic, medical, and nutritional advice (J had to maintain a body weight for his weight classification), meant that some degree of personal success was almost inevitable. At this point through self-report measures used to monitor the intervention, J reported increased confidence about retaining full fitness and refining his technique in preparation for the Games.

Finally, at this stage, J began to work regularly on his imagery skills (he was already reasonably proficient due to previous educational work), focusing on the other Olympic lift, the two hands clean and jerk, which was comparatively unaffected by his injury.

Stage three (Weeks 4–6). While Stage two was concerned with the discrimination and fading of kinesthesia between correct and incorrect catch positions, Stage three focused more on the consolidation of the correct movements through the use of mental skills. J's self-generated cues were clarified through discussion with his coaches, largely to establish their technical appropriateness. Once clarified and agreed, cues were then incorporated into an imagery script. The athlete started to image snatch performances (three to four times a week) both visually and kinesthetically, while reporting what he felt and saw, and how easy it was to form the image. Following recommendations consequent to the bioinformational imagery approach (Cuthbert, Vrana, & Bradley, 1991), progressive reinforcement and elaboration of the self-generated cues was used. So for example, as the athlete reported feeling the weight of the bar on his shoulders, this was incorporated into a refined imagery script, which continually evolved through ongoing debriefs and further refinement, as a method of shaping the desired technique.

Evolution of the script, and the imagery process itself, was consolidated by the use of self-modeling on prerecorded, edited videotapes. At regular intervals, J was filmed as he executed physical practice of the new version on light weights. He was encouraged to regularly watch this series of lifts, which provided him with an obviously improving profile of performance. Thus the improvements made during mental practice, were consolidated by the observation of his most recent best attempt. As the athlete improved, the model presented was changed to reflect the adaptive behavior (see Figure 2). The decision to update the best self-model was collaboratively decided between the athlete and coach. Video footage was also included of “big” lifts on the two hands clean and jerk, to maintain and enhance his confidence in this lift.

Finally, a longer-term plan was developed leading up beyond the Commonwealth Games to the Olympic Games, to be held in 2 years’ time. This was to further reinforce his positive long-term prospects.

Stage four (Weeks 6–9). With consent and ongoing monitoring by the team doctor and physiotherapist, J was instructed to build up the weight and the number of repetitions. As increased weight was added, the imagery script was adapted and the best self-model was changed for a more optimal model, serving to reinforce J’s self-efficacy. The potential for movement regression was addressed through constant coach supervision, reference to the most recent best self-model, and imagery practice. It was essential that J met the targets that he set himself during the early stages of the intervention. These targets reflected increased weight as well as process goals pertaining to the technique and mental skills. So far, he had been progressively and explicitly challenged by his own targets. More importantly, he had attained all of his goals.

Stage five (Weeks 9–10). Once athlete J had resumed lifting maximal weights, he was subjected to competitive simulated environments during training. The inclusion of added pressure (presence of selectors, gentle "baiting" by other team members, etc.) and the ability to provide feedback both qualitatively (via immediate video review) and quantitative (by means of kinematic information) were important facets of this final stage, as a way of convincing both J and the coach that the change was secure and therefore should not be altered again. Performance feedback and debrief with the coaches and the athlete was used to yet further refine the imagery script. The imagery which had been developed over a period of 6 weeks was incorporated into a pre-event preparation strategy.

Results

Technique

It was decided at the initiation of the intervention that J would need to flex the shoulder joint so that the force of the bar would act directly through the arm. During the injury, the force was acting behind the shoulder joint center. This created a large torque at the elbow and shoulder joints in both the right and left arm. Unfortunately, the torque required to correct the direction of force was so large that the ulna collateral ligament eventually ruptured. Figure 3 shows the angular displacements relative to the sagittal plane (not the absolute values) for the right shoulder and elbow (compare these with the targeted change shown in Figure 1). As the intervention progressed, the angle at the shoulder and elbow were minimized straightening the arm and positioning it in the direction of force. Consequently, the torques developed during earlier lifts were progressively reduced in the shoulder and elbow. This, in turn, reduced the pressure on the injured limb.

Figure 3 demonstrates the progressive shift towards recovery during the intervention. Furthermore, three follow up data acquisitions are included to demonstrate the long-term permanence of the technique change. There is an ongoing, albeit slight, improvement even 1 year after the cessation of the intervention, which was maintained at a 2 year follow-up.

Self-Perceptions

Two important psychological features were considered during the intervention. The first was self-efficacy, the second was imagery performance. Initially, athlete J set himself targets that he felt he would attain at least 80% of the time. As the intervention progressed, the tolerance for his targets were self-reduced to 60% and finally, to 40%. Although this is not a direct indicator of improved self-efficacy, it does reveal athlete J's efficacy to attain more demanding goals. During stage one of the intervention, athlete J reported an average efficacy score of 3. This was based on the immediacy of the injury, countered by his trust in the support team. During stages two and three, this score increased to 4. Athlete J reported that the rate of improvement seemed slow and his perception of performance readiness for the Commonwealth Games was in doubt. However, he was improving and therefore increased his score. By stage five, his average self-reported efficacy score had increased to 7; demonstrating an improvement in his self-efficacy over the intervention's duration and remained at this score at all follow up assessments. However, due to the ideographic nature of case studies, we stress that these results do not represent a common and standardized measure of improvement, since they are personal to the operational definitions laid down by each athlete. In this intervention, the Likert scores were used as a stimulant for discussion, which was deemed to be of much greater importance.

With regard to imagery ability, J reported increasingly high levels of vividness and controllability through the intervention which persisted over 3 years after the intervention during a future examination of all lifters in the weightlifting program. A post hoc review of the process showed that J perceived his ability to "come back from" the injury as a formative experience and an achievement in itself.

Performance

Performance wise, it is pleasing to report that J trained hard to the limits of his potential and competed in the Commonwealth Games completing a maximum of three out of three snatch lifts. Furthermore, he continued to improve his technique; as was evident at the following year's British Championships (see Figure 3, Week 55), the absence of subsequent injury, and his personal best of 107.5 kg at the next European Union Championships 2 years later. His subsequent established status as a National squad athlete (for 5 years post injury) and consistent selection for international competition, also attests to the quality of his recovery.

Discussion

It is particularly important for sport psychology as a discipline, and for the specific client–psychologist interaction, that the efficacies of interventions are increasingly demonstrated through objective measurement. Consequently, the present intervention utilized kinematic techniques and performance measures, as well as the more usual self-report indices, to provide this evidence. On evaluation of the elbow and shoulder kinematics, there appeared to be a great deal of positive change. The athlete successfully refined the injurious technique in accordance with the suggested manipulation through the observational learning and imagery-based procedure. Consequently, this served to enhance specific psychological characteristics, his career, and performance development.

As a notable feature of the case study presented, we advocate the systematic use of multiple tools to facilitate technical change in skills that are already well-established, coupled with necessary positive psychological change. In this particular case, we used contrast training to differentiate movement patterns followed by a progressive shaping methodology, and concluding with necessary steps to internalize and then increase resistance to stressors through appropriate pressure testing. Whereas previous studies have employed similar techniques as contrast training, for example Hanin et al.'s (2002) "Old way/New way," we suggest that shaping and pressure testing are essential *additional* steps to ensuring a robust departure from one movement pattern to another.

From a technical perspective, the theoretical research by Walter and Swinnen (1994) suggests that athletes with an already well-established technique could possess bad habits as a result of incorrect skill acquisition. Fortunately, this has been shown to be resolvable, and in a short time period. Experimentally, Zanone and Kelso (1992) explained that smaller changes would be more realistic in such circumstances, owing to the high level of similarity between the two behavioral states; however, this appeared to disagree with findings from the applied setting (Trower, 1996). Indeed, later research confirmed this view, demonstrating that close similarities between behaviors result in only short-term permanency when compared to movements that were more distinct from one another (Kostrubiec et al., 2006). Relating these findings against our applied intervention, it appears that this research does not sufficiently represent the totality of challenge faced by elite-level athletes. Based on the evidence in this case study, three strategies should be employed for maximum effect: contrast training, then shaping, followed by pressure testing. As an essential procedure to ensure the formation of a new movement pattern, conscious contrast (deautomation) between the already well-established and to-be-learned pattern must take place; thus supporting the idea of distinction between subtly different movement patterns. This should be followed by progressively shaping the technique; supporting a process of smaller but gradually more accurate approximations of the target behavior. In other words, technical change can be viewed as a process of generating an "uncomfortable" alternative, although technically more desirable, followed by gradually increasing the "comfort" of this new version, while at the same time decreasing the comfort levels of the original version.

As an additional benefit of this case study, athlete J commented consistently throughout the intervention on his perceived improvement in self-efficacy. One may argue that efficacy developed by the athlete was more of a mediating factor in bringing about change (Bandura, 1997). Indeed, observational learning, more specifically the use of coping models, have been shown to increase levels of self-efficacy in comparison to the more commonly employed skilled model (Ste-Marie et al., 2012). It has long been recognized that imagery and observational learning interventions can serve different roles. Hall, Mack, Paivio, and Hausenblas (1998) suggest that there are different "types" of images that may serve either a cognitive or a motivational function. Therefore, the nature of the problem may dictate whether self-coping, "other," or mastery models would be best suited. The characteristics of the task, problem, and performer should all have a bearing on the inclusion of a best self-model as part of an intervention. The literature base, so far, concerns itself with how a specific model characteristic affects performance. However, little effort has been expended in trying to establish the optimal characteristics of a model for different classifications of individuals and/or problems, such as technical change in experienced populations. This case study supports the use of imagery and observational learning as both informational (technical change) and motivational (self-efficacy) coaching tools.

In summary, this particular case study employed a series of techniques that appear to have been very successful in meeting the intended outcomes for this individual. Reflecting the need for established and effective training programs at this level of motor control, a greater understanding of the refinement process and previously successful methods employed is essential, probably again, through various case study examples (see Carson & Collins, 2011), with results presented in tandem with the logic underlying the decision to use that particular approach (Barker, Mellalieu, McCarthy, Jones, & Moran, 2012). With respect to the intervention design, it is worth noting the "trade off" decisions which were taken at each stage. The complexity of the human condition, added to the various challenges of competitive sport, dictate that no one approach will offer a perfect fit to the needs of the intervention. Of course, this planning necessity is well known to experienced consultants (cf. Murphy, 1995) but should beneficially be exposed when presenting case studies. Research in a variety of settings demonstrates the importance of the reasoning process as both a feature of expertise and a crucial aspect of education and professional development (Martindale & Collins, 2007).

Although not the primary focus of this paper, another important consideration was the use of an interdisciplinary support team to rehabilitate athlete J's technique and injury. Working relationships between the coaches, doctor, physiotherapist, and psychologists were most important, with each having clearly defined and well accepted roles. Co-operation towards a set of mutually accepted goals, with each team member telling the same story, can only emerge from such a secure and prenegotiated position. Accordingly, it is a pertinent part of the sport psychologist's role to develop this team approach. The potential for conflict in such teams has already been addressed (Reid, Stewart, & Thorne, 2004) but sport psychology may well benefit from the application of occupational and organizational approaches to optimize the sport science/sport medicine/coach/athlete dynamic (Burke, 2011). Consideration of all these factors will ensure that athletes receive the optimum level of service.

More interesting however, is the approach to securing the new technique under pressure. The inclusion of pressure testing as a means of building self-efficacy, coupled with quantitative evidence to demonstrate that the changes had been made securely, reflects the holistic nature of this case study and an important consideration of transfer to representative competition. Furthermore, the notion of convincing both athlete and coach that the technique no longer requires further modification (tweaking), represents an important avenue of our future research concerning multiple fields, including: motor control, sport psychology, and coaching practice. It is hoped that this will extend the work and contribution of sport psychologists towards the achievement of excellence in elite sport settings.

References

Abdel-Aziz, Y. I., & Karara, H. M. (1971, August). *Direct linear transformation from comparator coordinates into space coordinates in close range photogrammetry.* Paper presented at the Symposium on Close Range Photogrammetry, Falls Church, Virginia.

Ashford, D., Bennett, S. J., & Davids, K. (2006). Observational modeling effects for movement dynamics and movement outcome measures across differing task constraints: A meta-analysis. *Journal of Motor Behavior, 38*, 185–205. doi: 10.3200/jmbr.38.3.185-205

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*, 191–215. doi: 10.1037/0033-295x.84.2.191

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: Freeman.

Baquie, P., & Brukner, P. (1997). Injuries presenting to an Australian sports medicine centre: A 12-month study. *Clinical Journal of Sport Medicine, 7*, 28–31.

Barker, J. B., Mellalieu, S. D., McCarthy, P. J., Jones, M. V., & Moran, A. (2012). A review of single-case research in sport psychology 1997–2012: Research trends and future directions. *Journal of Applied Sport Psychology, 25*, 4–32. doi: 10.1080/10413200.2012.709579

Bartlett, R. M., & Bowden, T. (1993). *The kine system users guide*. Alsager: The Manchester Metropolitan University.

Beilock, S. L., Bertenthal, B. I., McCoy, A. M., & Carr, T. H. (2004). Haste does not always make waste: Expertise, direction of attention, and speed versus accuracy in performing sensorimotor skills. *Psychonomic Bulletin & Review, 11*, 373–379. doi: 10.3758/BF03196585

Boyce, B. A. (1991). Beyond show and tell: Teaching the feel of the movement. *Journal of Physical Education, Recreation and Dance, 62*, 18–20. doi: 10.1080/07303084.1991.10606530

Burke, V. (2011). Organizing for excellence. In D. Collins, A. Button & H. Richards (Eds.), *Performance psychology: A practitioner's guide* (pp. 99–119). Oxford: Elsevier.

Carron, A. V. (1988). *Group dynamics in sport*. Eastbourne: Sports Dynamics.

Carson, H. J., & Collins, D. (2011). Refining and regaining skills in fixation/diversification stage performers: The Five-A Model. *International Review of Sport and Exercise Psychology, 4*, 146–167. doi: 10.1080/1750984x.2011.613682

Collins, D., Morriss, C., & Trower, J. (1999). Getting it back: A case study of skill recovery in an elite athlete. *The Sport Psychologist, 13*, 288–298.

Cross, E. S., Schmitt, P. J., & Grafton, S. T. (2007). Neural substrates of contextual interference during motor learning support a model of active preparation. *Journal of Cognitive Neuroscience, 19*, 1854–1871. doi: 10.1162/jocn.2007.19.11.1854

Cuthbert, B. N., Vrana, S. R., & Bradley, M. M. (1991). Imagery: Function and physiology. In J. R. Jennings, P. K. Ackles & M. G. H. Coles (Eds.), *Advances in psychophysiology* (Vol. 4, pp. 1–42). New York: Jessica Kingsley Publishers.

Fitts, P. M., & Posner, M. I. (1967). *Human performance*. California: Brooks/Cole Publishing Company.

Hall, C. R., Mack, D. E., Paivio, A., & Hausenblas, H. A. (1998). Imagery use by athletes: Development of the Sport Imagery Questionnaire. *International Journal of Sport Psychology, 29*, 73–89.

Hanin, Y., Korjus, T., Jouste, P., & Baxter, P. (2002). Rapid technique correction using old way/new way: Two case studies with Olympic athletes. *The Sport Psychologist, 16*, 79–99.

Hartfield, D. (1994). *British amateur weight lifter's association handbok*. London: BAWLA.

Hedrick, A., & Wada, H. (2008). Weightlifting movements: Do the benefits outweigh the risks? *Strength & Conditioning Journal, 30*, 26–35. doi: 10.1519/SSC.0b013e31818ebc8b

Holmes, P. S., & Calmals, C. (2011). Mental practice: Neuroscientific support for a new approach. In D. Collins, A. Button & H. Richards (Eds.), *Performance psychology: A practitioner's guide* (pp. 231−244). Oxford: Elsevier.

Jenkins, S. (2008). Can elite tournament professional golfers prevent habitual actions in their putting actions? *International Journal of Sports Science and Coaching, 3*, 117–127. doi: 10.1260/174795408785024108

Kazdin, A. E. (1982). The separate and combined effects of covert and overt rehearsal in developing assertive behavior. *Behaviour Research and Therapy, 20*, 17−25. doi: 10.1016/0005-7967(82)90004-3

Kostrubiec, V., Tallet, J., & Zanone, P.-G. (2006). How a new behavioral pattern is stabilized with learning determines its persistence and flexibility in memory. *Experimental Brain Research, 170*, 238–244. doi: 10.1007/s00221-005-0208-6

Lang, P. J. (1979). A bio-informational theory of emotional imagery. *Psychophysiology, 16*, 495−512. doi: 10.1111/j.1469-8986.1979.tb01511.x

Lephart, S. M., Pincivero, D. M., Giraldo, J. L., & Fu, F. H. (1997). The role of proprioception in the management and rehabilitation of athletic injuries. *The American Journal of Sports Medicine, 25*, 130–137.

MacNamara, Á., Holmes, P., & Collins, D. (2008). Negotiating transitions in musical development: The role of psychological characteristics of developing excellence. *Psychology of Music, 36*, 335−352. doi: 10.1177/0305735607086041

MacPherson, A. C., Turner, A. P., & Collins, D. (2007). An investigation of natural cadence between cyclists and noncyclists. *Research Quarterly for Exercise and Sport, 78*, 396–400. doi: 10.1080/02701367.2007.10599438

Maddison, R., Prapavessis, H., & Clatworthy, M. (2006). Modeling and rehabilitation following anterior cruciate ligament reconstruction. *Annals of Behavioral Medicine, 31*, 89−98.

Magyar, T. M., & Duda, J. L. (2000). Confidence restoration following athletic injury. *The Sport Psychologist, 14*, 372–390.

Martindale, A., & Collins, D. (2007). Enhancing the evaluation of effectiveness with professional judgment and decision making. *The Sport Psychologist*, *21*, 458–474.

Martindale, A., & Collins, D. (2012). A professional judgment and decision making case study: Reflection-in-action research [Special issue]. *The Sport Psychologist*, *26*, 500–518.

McCullagh, P. (1986). Model status as a determinant of observational learning and performance. *Journal of Sport Psychology*, *8*, 319−331.

McCullagh, P., Weiss, M. R., & Ross, D. (1989). Modeling considerations in motor skills performance: An integrated approach. In K. B. Pandolf (Ed.), *Exercise and sport science reviews* (pp. 475–513). Baltimore: Williams and Wilkins.

Mercado, E., III. (2008). Neural and cognitive plasticity: From maps to minds. *Psychological Bulletin*, *134*, 109–137. doi: 10.1037/0033-2909.134.1.109

Morris, T., Spittle, M., & Watt, A. P. (2005). *Imagery in sport*. Champaign, IL: Human Kinetics.

Murphy, S. M. (1995). *Sport psychology interventions*. Champaign, IL: Human Kinetics.

Oudejans, R. R. D., Koedijker, J. M., & Beek, P. J. (2007). An outside view on Wulf's external focus: Three recommendations. *E-journal Bewegung und Training*, *1*, 41–42.

Podlog, L., Dimmock, J., & Miller, J. (2011). A review of return to sport concerns following injury rehabilitation: Practitioner strategies for enhancing recovery outcomes. *Physical Therapy in Sport, 12*, 36−42. doi: 10.1016/j.ptsp.2010.07.005

Reid, C., Stewart, E., & Thorne, G. (2004). Multidisciplinary sport science teams in elite sport: Comprehensive servicing or conflict and confusion? *The Sport Psychologist, 18*, 204–217.

Rendell, M. A., Farrow, D., Masters, R., & Plummer, N. (2011). Implicit practice for technique adaptation in expert performers. *International Journal of Sports Science and Coaching, 6*, 553–566. doi: 10.1260/1747-9541.6.4.553

Rushall, B. S. (1988). Covert modeling as a procedure for altering an elite athlete's psychological state. *The Sport Psychologist, 2*, 131−140.

Schmidt, R. A., & Bjork, R. A. (1992). New conceptualizations of practice: Common principles in three paradigms suggest new concepts for training. *Psychological Science, 3*, 207–217. doi: 10.1111/j.1467-9280.1992.tb00029.x

Shadmehr, R., Smith, M. A., & Krakauer, J. W. (2010). Error correction, sensory prediction, and adaptation in motor control. *Annual Review of Neuroscience, 33*, 89–108. doi: 10.1146/annurev-neuro-060909-153135

Smith, D., Holmes, P. S., Whitemore, L., & Devonport, T. (2001). The effect of theoretically-based imagery scripts on field hockey performance. *Journal of Sport Behavior, 24*, 408–419.

Ste-Marie, D. M., Law, B., Rymal, A. M., Jenny, O., Hall, C., & McCullagh, P. (2012). Observation interventions for motor skill learning and performance: An applied model for the use of observation. *International Review of Sport and Exercise Psychology, 5*, 145–176. doi: 10.1080/1750984X.2012.665076

Trower, J. (1996, September). *Athlete, coach and sport scientist: Working in partnership.* Paper presented at the Annual Conference of the British Association of Sport and Exercise Sciences, Lilleshall.

Walter, C. B., & Swinnen, S. P. (1994). The formation and dissolution of ‘bad habits’ during the acquisition of coordination skills. In S. P. Swinnen, H. Heuer, J. Massion & P. Casaer (Eds.), *Interlimb coordination: Neural, dynamical, and cognitive constraints* (pp. 492–510). San Diego, CA: Academic Press.

Winter, S., & Collins, D. (2013). Does priming really put the gloss on performance? *Journal of Sport and Exercise Psychology, 35*, 299–307.

Woods, K., Bishop, P., & Jones, E. (2007). Warm-up and stretching in the prevention of muscular injury. *Sports Medicine, 37,* 1089–1099.

Zanone, P. G., & Kelso, J. A. S. (1992). Evolution of behavioural attractors with learning: Nonequilibrium phase transitions. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 403–421. doi: 10.1037/0096-1523.18.2.403

Zatsiorski, V. M. (1995). *Science and practice of strength training*. Champaign, IL: Human Kinetics.

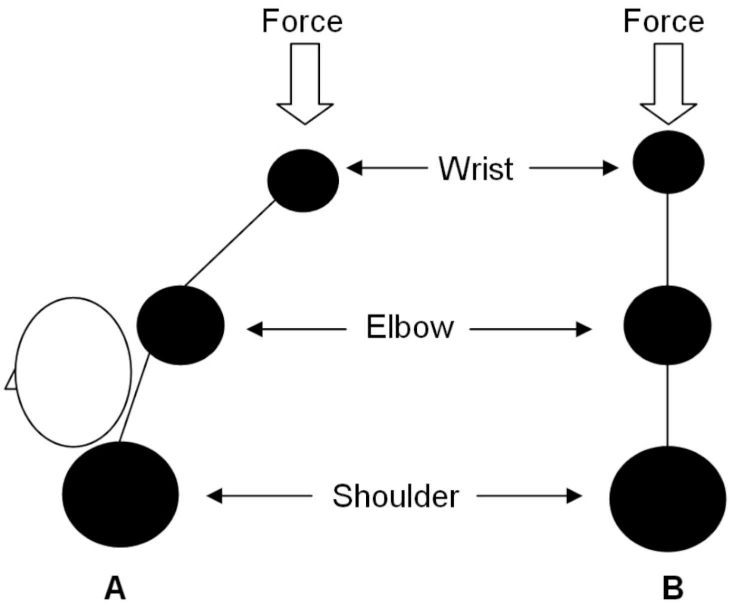

Figure 1. Schematic showing the injurious right arm complex prior to the intervention (A) and the target technical change (B) which was the goal of the intervention.

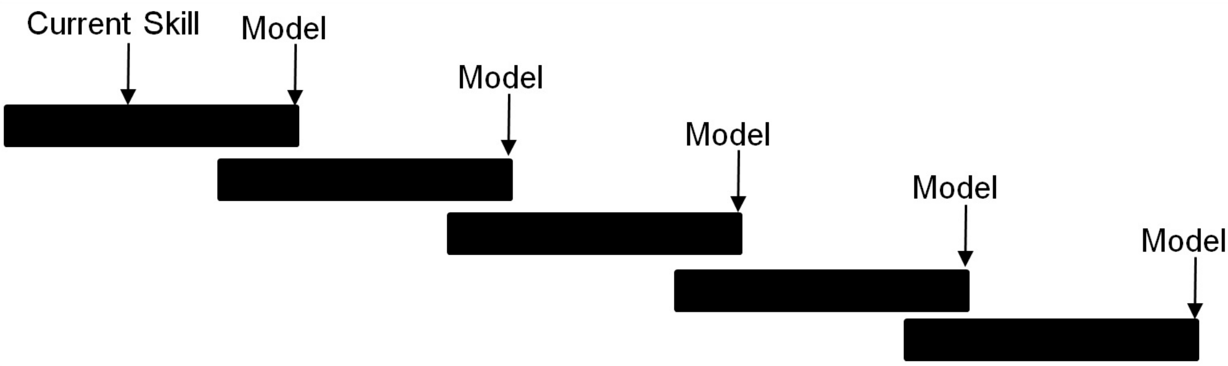

Figure 2. Shaping methodology; the athlete observes a best self-model based on his best actual attempt (closest approximation) of the target behavior. As the athlete progresses towards the target behavior, the model based on his best attempt is changed.

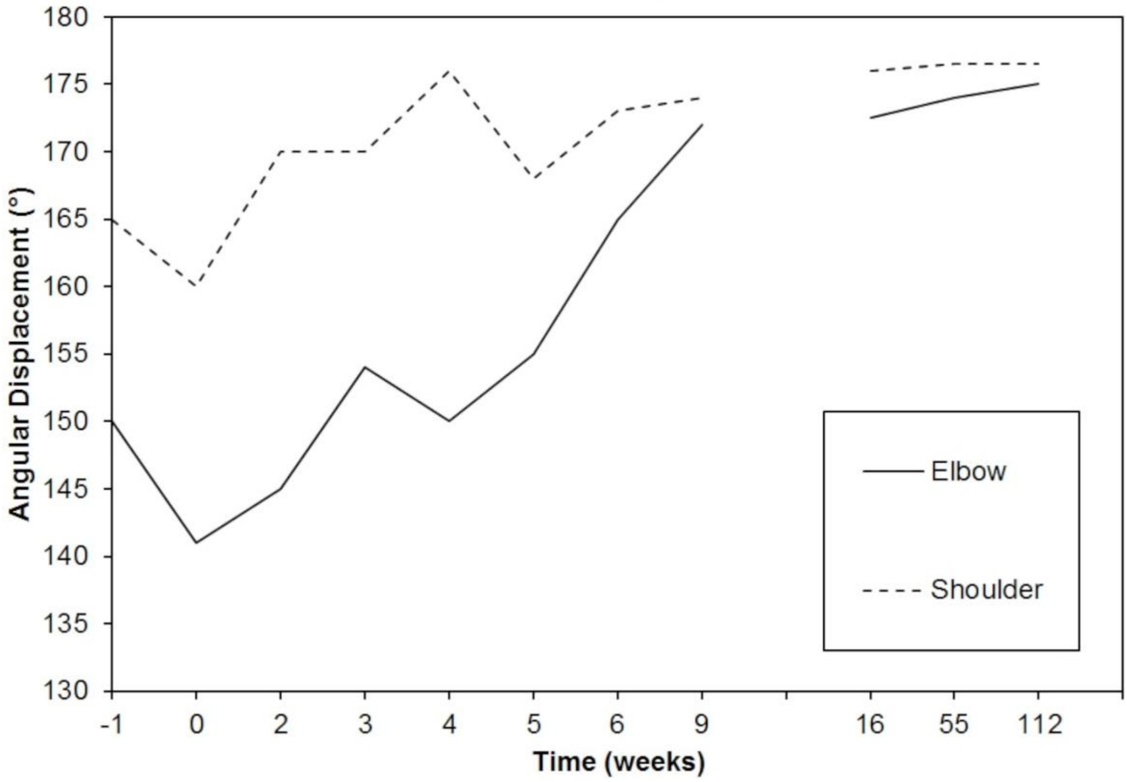

Figure 3. Lifter's angular displacement at elbow and shoulder 1 week prior to injury (−1 week), the injury itself (Week 0), through the progression of the intervention (Weeks 2–6), in competition after 1 year following injury (Week 55), and 2 years (Week 112).