APPLIED INSIGHTS

Pronounced inter-limb asymmetry in an international female 400m athlete: a 14-week case study using periodised strength training

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INTRODUCTION

Evidence-based literature relating to training interventions for international sprint athletes is scarce, which is surprising given the gravitas associated with trying to be the 'fastest in the world.' When developing physical qualities for speed, numerous studies have highlighted the importance of strength,[11,27,29] power[11,19,22] and reactive strength.[20,26] However, the majority of studies have focused on improving short distance sprint performance (0-40m), most likely because collegiate or team sport athlete samples are used, which frequently require short distances sprints prior to some element of directional change.[16,21] Although this information is useful (and not disputed), literature pertaining to the physical requirements for competitive international track athletes is rare, arguably due to the limited samples to which coaches may have access. With that in mind, individual case reports offer a viable means of transferring useful information regarding the efficacy of strength and conditioning (S&C) training for international sprint athletes.

This case report is about an international female sprint athlete who has represented Great Britain at the 400m since 2017. After competing at the European Indoor Championships in early 2017, she experienced a herniated disc in her lumbar spine (L4-L5) during training, after landing off-balance during a hurdling technique. Consequently, she ran no further competitive races for the remainder of 2017, meaning that the entire outdoor season (April – September) was missed. The athlete underwent physiotherapy treatment from March–September 2017, before being cleared to begin weight room and running training again in October.

This report sets out to highlight the training process that was undertaken for this sprint athlete. From a strength perspective, details include: pre-testing (week 1), three training phases (strength endurance, strength, and maximal strength) of four weeks each, and post-testing (week 14) in an attempt to prepare her for the first race of the indoor 2018 season.

An overview of her running training throughout the same time frame has also been included to provide greater context of how this training was re-introduced after more than six months of no running.

METHODS

ATHLETE DESCRIPTION

One international female sprinter (age: 25 years; height: 1.69 m; body mass: 56.7 kg [pre-testing]) participated in this case study. The athlete was an elite sprinter with 11 years of competitive experience of sprinting, but limited structured experience for S&C training. Personal best times for the 400 and 800m were 52.99 and 2:07.5s respectively, both achieved in 2017. Despite being a 400m competitor, the athlete focused on longer distance events (such as the 800m) during the indoor season. Having been cleared for participation in strength training by a qualified physiotherapist, the athlete was informed of all testing procedures and provided written informed consent for the writing of this case study.

CASE STUDY DESIGN

This case study employed a repeated measures observational design on a single athlete as per previous guidelines.[9] Pre-testing took place in mid-October (week 1) and post-testing (week 14) in the first week of February, noting that there was one week of no training over the Christmas period in December. However, during this week, the athlete continued with remedial strategies outlined as part of the warm-up procedure daily (outlined in the training programmes). Weight room training was conducted twice a week (Monday and Wednesday) for 12 weeks throughout three different phases of training: strength endurance, strength, and maximal strength; each phase of training lasting for four weeks. Running training was also conducted three times per week (Tuesday, Thursday and Saturday) and – given that this was re-introduced after more than six

Table 1: Example running sessions conducted throughout the training intervention period

BLOCK 1	BLOCK 2	BLOCK 3
4 x 200 m @ 60-70% RPE (3 mins rest between each)	5 x 170 m @ 80% RPE (3 mins rest between each)	8 x 220 m @ 90% RPE (5 mins rest between each)
10 x 70 m hills @ 60-70% RPE (walk back between efforts)	8 x 70 m hills @ 80% RPE (walk back between efforts)	4 x 150 m hills @ 90% RPE (walk back between efforts)
5 km park run	5 km park run	5 km park run
RPE = rate of perceived exertion		

Figure 1: Grading criteria for the overhead squat assessment (in line with suggestions from Bishop et al[4])

JOINT	COMPENSATION	LEFT	RIGHT	NOTES
Foot/ankle	External rotation	○	○	
	Feet flatten	○	○	
	Heel raise	○	○	
Knee	Valgus	⊙	⊙	Larger on R
	Varus	○	○	
LPHC	Forward lean	⊙		Poor depth
	Lumber arching	○		
	Lumber rounding	○		
Shoulder	Arms fall forward	○	○	
	Elbows flex	○	○	
Head	Protruding	○		

months off – a somewhat experimental approach to sessions was conducted with respect to the intensity of each session (Table 1). Particular attention was paid to subjective feedback from the athlete on how each session felt, so as to guide future sessions during this re-integration period. Typically, two sessions followed an interval training format each week, focusing on relatively short distances (relative to the 400m event), as speed development was considered a major priority for the upcoming season.

ATHLETE TEST BATTERY

Read[23] offered a proposed test battery for sprinters and outlined the importance of strength, power, and reactive strength. However, owing to the limited experience of this athlete, a decision was made to keep testing protocols simple in the initial stages of the monitoring process. After discussions with the physiotherapist, it was agreed that the test battery would include: the overhead squat (movement screen), kneeling weight bearing lunge test (ankle mobility and asymmetries), countermovement jump (CMJ) and single leg countermovement jump (SLCMJ) (vertical jump ability and asymmetries), and triple hop test (repeated effort horizontal jump ability and asymmetries). With the exception of the overhead squat, three trials were performed for each test (with a rest period of 60 seconds between trials and 3 minutes between tests) and the best trial was used to report pre and post-test values. Details of test protocols are below.

Overhead squat

Test protocols were conducted in line with suggestions by Bishop et al (see Figure 1).[4] The athlete was instructed to set her feet hip-width apart with toes pointing forward. Arms were positioned overhead in full shoulder flexion with the head and eyes looking forward, facilitating a neutral neck position. The screen was conducted barefoot (as per standardised instructions so that no assistance was provided for potentially reduced ankle mobility).[4] Five repetitions were performed viewing from the front, and five from a lateral perspective, with movement quality assessed in real time in line with the suggested grading criteria from Bishop et al.[4]

Weight bearing lunge test

Test protocols were conducted in line with suggestions by Howe.[15] The test was performed barefoot with the second toe, calcaneus, and patella all positioned perpendicular to the wall. The athlete's subtalar joint was kept in neutral to prevent extra ankle range of motion being recorded in a compensated pattern. Once set-up had been completed, the athlete lunged forward until the knee made contact with the wall, ensuring no heel elevation occurred throughout.[15] If a successful repetition was completed, the foot was repositioned 1 cm further away from the wall and the process repeated until maximal distance was observed with no compensation. To ensure no compensations were present during trials, a rubber band was placed under the heel as per previous guidelines.[3] For reference, normative data in healthy adults has been reported as 10-13 cm.[5]

Table 2: Strength endurance training programme (conducted twice a week for four weeks)

LIFT/EXERCISE	SETS	REPETITIONS	LOAD *	REST
FOAM ROLLING (1-2 MINUTES PER MUSCLE GROUP):				
Gastrocnemius, TFL, thoracic spine				
DYNAMIC STRETCHING (1 x 8-10 REPETITIONS PER EXERCISE):				
Forward lunges, inchworms, lateral lunges, lunge (T-spine rotation), ankle mobility				
BB split squat	3	8 each side	65-75%	4 minutes
Drop lands (30 cm)	3	5	-	do in rest
Single arm DB row	3	8 each side	65-75%	4 minutes
SL squat (to box)	3	6 each side	-	do in rest
BB hip thrust	3	8	65-75%	4 minutes
Lateral pillar	3	3 x 30s	-	do in rest

* 1RM loads were not tested; thus these were approximations based on athlete feedback BB = barbell, DB = dumbbells, SL = single leg

Table 3: Strength training programme (conducted twice a week for four weeks)

LIFT/EXERCISE	SETS	REPETITIONS	LOAD *	REST
FOAM ROLLING (1-2 MINUTES PER MUSCLE GROUP):				
Gastrocnemius, TFL, thoracic spine				
DYNAMIC STRETCHING (1 x 8-10 REPETITIONS PER EXERCISE):				
Forward lunges, inchworms, lateral lunges, lunge (T-spine rotation), ankle mobility				
BB box squat	4	6	80-85%	4 minutes
CMJ	4	4	-	do in rest
BB shoulder press	4	6	80-85%	4 minutes
DB walking lunges	2	6 each side	Light DBs	do in rest
BB Romanian deadlift	4	6	80-85%	4 minutes
Ball rollouts	2	10	-	do in rest

* 1RM loads were not tested; thus these were approximations based on athlete feedback BB = barbell, CMJ = countermovement jump, DB = dumbbells

Countermovement jump and single leg countermovement jump

Jump testing was conducted using the optical measurement system OptoJump, which has reported near-perfect reliability and been shown to be strongly correlated with force platforms for the assessment of jump height.[12] All jumps were initiated by performing a countermovement to a self-selected depth, before accelerating vertically as explosively as possible into the air. Legs were required to remain fully extended and hands fixed to hips throughout the flight phase of the jump before landing back in between the optical measurement system. The recorded metric for all CMJ tests was jump height (calculated from the flight time method).

Triple hop (for distance)

The athlete began by standing on the designated testing leg with toes behind the starting line. Upon instruction, she took three maximal hops forward (landing on the same leg throughout) with the intention of minimising ground contact times after the first and second hops. When landing from the final hop, she was required to 'stick' the landing and hold for two seconds. Failure to stick the final landing resulted in a void trial and the jump being retaken after a 60-second rest. The distance hopped from the starting line to the landing position of the heel was then measured and recorded to the nearest centimetre.

TRAINING INTERVENTION

Three four-week training blocks were programmed in a linear periodised structure before post-testing protocols were conducted. Owing to the reduced S&C experience of the athlete and necessity to promote robustness (in an attempt to reduce future risk of injury), training blocks of strength endurance (Table 2), strength (Table 3) and maximal strength (Table 4) were programmed for the first three months. The main aims throughout this intervention were to increase the athlete's physical literacy in the weight room and reduce inter-limb imbalances determined from pre-testing (Table 5). All sessions were programmed and supervised by an accredited S&C coach.

STATISTICAL ANALYSIS

Data were computed in Microsoft Excel and later transferred into SPSS (V.24) for additional reliability analyses. Absolute reliability of test protocols was computed via the coefficient of variation (CV) with values <10% deemed acceptable.[10] Relative reliability was computed using the intraclass correlation coefficient (ICC) with absolute agreement and interpreted in line with previous suggestions: >0.9 = excellent, 0.75-0.9 = good, 0.5-0.75 = moderate, and <0.5 = poor.[17] To quantify change between pre and post-test scores, effect sizes (ES) were calculated using the equation $(Mean_{post} - Mean_{pre} / SD_{pooled})$ and interpreted in line with

Table 4: Maximal strength training programme (conducted twice a week for four weeks).

LIFT/EXERCISE	SETS	REPETITIONS	LOAD *	REST
FOAM ROLLING (1-2 MINUTES PER MUSCLE GROUP):				
Gastrocnemius, TFL, thoracic spine				
DYNAMIC STRETCHING (1 x 8-10 REPETITIONS PER EXERCISE):				
Forward lunges, inchworms, lateral lunges, lunge (T-spine rotation), ankle mobility				
BB back squat	4	3–4	85-90%	4 minutes
Drop jump	4	4	-	do in rest
BB push press	4	4	85-88%	4 minutes
DB RFESS	2	6 each side	Light DBs	do in rest
BB Romanian deadlift	4	5	85%	4 minutes
Kneeling cable chop	2	6 each side	-	do in rest

* 1RM loads were not tested; thus these were approximations based on athlete feedback BB = barbell, DB = dumbbells, RFESS = rear foot elevated split squat

previous suggestions: <0.2 = trivial, 0.2-0.59 = small, 0.6-1.19 = moderate, 1.2-1.99 = large, and >2.0 = very large.[28] In addition, percentage change from pre to post was also calculated. Finally, inter-limb asymmetries were calculated using the percentage difference method 100/(max value)*(min value)*-1+100.[5,6]

Results

The overhead squat screen highlighted that the athlete's motor patterning during the squat was poor. There was an inability to achieve sufficient depth (quadriceps parallel with the floor as a minimum requirement) with noticeable knee valgus on both limbs during the descent (more so on the right side). Pre and post-testing results are presented in Table 5 with large to very large effect sizes reported for each test. All test measures reported good to excellent reliability (ICC=0.82-0.97) and acceptable between-trial consistency (CV=≤ 6%) (Table 6). As previously described, the athlete focused on running the 800m during the indoor season and in her first competitive race post-spinal injury, ran 2:07.19s, a new personal best and an improvement of 0.31 seconds over the previous best.

Discussion

The aim of this case report was to highlight the results of a three-month S&C training programme undertaken with an international female 400m athlete after suffering a severe spinal injury. Results showed that, despite minimal emphasis on speed and power training during the S&C-based sessions, a linear periodisation structure focusing on strength endurance and strength is effective at improving ballistic test measures in an elite track athlete; it may have also contributed to her improved running performance. It should be recognised at this stage, however, that this athlete had limited experience in a structured strength training regime; thus, reported improvements in the selected tests are perhaps somewhat expected.

Details of this athlete's running training are provided in Table 1. Noting that the current period was considered a reintegration phase for this athlete, session intensity was often guided via continued feedback from the athlete, based on rate of perceived exertion (RPE). As such, there is a clear trend in how session intensity was typically progressed throughout each block in an attempt to prepare the athlete for higher intensity running and upcoming events during the indoor season. It should also be noted that despite clear communication channels between all parties involved (athlete, track coach, physiotherapist, and S&C coach), this part of the athlete's training repertoire did not fall under the remit of the S&C coach. In addition, it should be recognised that the successful reintegration of running – with a progressive intensity prescribed throughout – undoubtedly played a major part in her successful first race back during the indoor season.

Results from this case study demonstrate that a three-month strength endurance and strength training programme is an effective intervention for improving lower body power and ankle mobility. All jump tests showed substantial improvement in post-test results (ES range = 1.3-2.0), the largest of which was seen in the SLCMJ for the left limb which showed a 23.5% improvement. When left and right limb scores are compared, it is evident that the left limb scored noticeably worse than the right for all tests during pre-testing; thus, it is encouraging to see greater percentage improvements on this side. An important point to note is that no additional work was performed by the left limb to facilitate this improvement. Rather, as the first training programme shows (Table 2), a greater emphasis was given to unilateral-based training with the selection of exercises such as split squats and single leg squats.

This is in contrast to previous research from Brown et al,[9] who purposefully incorporated supplementary training for the weaker limb in conjunction with an additional bilateral training programme. Results from Brown et al showed that increases in horizontal force production were evident in the weaker limb; however, this was specific to sprint testing on a non-motorised treadmill for six seconds; thus, direct comparisons between the present study and results from Brown et al should not be drawn. In addition, substantial improvements in the weaker limb were noted for this athlete, but without additional exercises programmed; thus, it would appear that both methods could be viable for improving performance. The common denominator in both the present study and that of Brown et al[9] is the programming of unilateral strength exercises; therefore, it is advised that these may benefit sprint athletes and should be incorporated into S&C

Table 5: Pre and post-test battery results

TIME POINT	WBLT (CM) LEFT/RIGHT	WBLT ASYM %	CMJ (M)	SLCMJ (M) LEFT/RIGHT	SLCMJ ASYM %	TRIPLE HOP (M) LEFT/RIGHT	TRIPLE HOP ASYM %
Pre	1.9/4.2	54.76	0.36	0.17/0.20	15.00	5.40/5.75	6.09
Post	6.8/7.8	12.82	0.41	0.21/0.22	4.55	5.85/6.10	4.10
Cohen's *d*	1.4/1.4	-	1.3	1.3/2.0	-	1.4/1.4	-
% Change	257.9/85.7	-	13.9	23.5/10.0	-	8.3/6.1	-

WBLT = weight bearing lunge test, CMJ = countermovement jump, SLCMJ = single leg countermovement jump, cm = centimetres, m = metres, Asym = asymmetry

Table 6: Reliability of jump test protocols quantified from pre-test scores

RELIABILITY MEASURE	CMJ	SLCMJ (L)	SLCMJ (R)	TRIPLE HOP (L)	TRIPLE HOP (R)
CV (%)	1.62	3.46	5.97	2.59	5.19
ICC	0.97	0.95	0.89	0.82	0.86

CMJ = countermovement jump, SLCMJ = single leg countermovement jump, L = left, R = right, CV = coefficient of variation, ICC = intraclass correlation coefficient

programmes, especially for athletes exhibiting large (>10%) asymmetries.[8]

Ankle mobility was very poor for this athlete during pre-testing, noting that average scores for the weight-bearing lunge test have been reported between 10-13 cm.[15] With both limbs well below 10 cm, increasing ankle mobility was deemed a priority. During the warm-up, foam rolling was prescribed for the gastrocnemius muscle (two minutes per side) and ankle mobilisations in the form of the weight-bearing lunge exercise (20 repetitions per limb). It should also be noted that all foam rolling and dynamic stretches were performed prior to running training which occurred three times per week; thus, these remedial strategies were completed a total of five times per week. From a strength perspective, exercises that encouraged active dorsiflexion such as split squats, rear foot elevated split squats, and back squats were programmed to facilitate further improvements in ankle mobility. Despite large improvements in post-testing scores, it should be acknowledged that values of 6.8 and 7.8 cm are still low; thus, improving ankle range of motion continued as a priority during the next block of training.

The final point of discussion relates to inter-limb asymmetries. Previous literature has highlighted that differences of 7-10% are associated with reduced physical performance[1,6,8,14] and increased injury risk.[18,24] Asymmetries for the SLCMJ were 15% (which can be considered large) and for ankle mobility were 55% (which can be considered extremely large) during pre-testing; thus, these results were also a strong consideration for programme design. Previous research has highlighted that both unilateral[9,13,25] and bilateral training[2] are effective methods at reducing inter-limb asymmetries. Intuitively though, it seems logical that unilateral training would be more effective at reducing asymmetries, given that each limb is targeted individually and previous literature has suggested incorporating unilateral strength and power exercises into traditional bilateral training programmes.[7] When Table 2 is viewed, it is evident that greater emphasis on unilateral training was given during the initial stages of training. However, inclusion of exercises such as walking lunges and rear foot elevated split squats were programmed in the final two blocks to ensure some element of unilateral training was maintained. Consequently, it was encouraging to see asymmetries drastically reduce during post-testing.

In conclusion, linear periodisation that focused on strength endurance and strength was an effective method of improving lower body power, reducing inter-limb asymmetries, and likely contributing to improved running performance. Future analysis should focus on whether such interventions are also applicable to the athlete's preferred race distance (400m) and also to determine the effects of power and plyometric training on sprint performance, given this likely represents a stronger association to sport-specificity.

Practical applications

Practitioners can use the information in this case study to show the effectiveness of a three-month strength training intervention for track athletes. Of particular note, given the low S&C training age for this particular athlete, a decision was taken to prioritise exercises such as split squats, single leg squats and lunges, which proved to be an effective strategy for minimising asymmetries and improving performance. However, it is plausible that prioritising bilateral lifts first (such as back squats and deadlifts) would have achieved the same. Thus, regular testing will enable practitioners to monitor the effectiveness of their interventions, which should enable optimised performance enhancement to be maintained on an individual level.

A final consideration is that practitioners should aim to recognise the individual requirements of their athletes. Although the results of the present case study can be viewed as 'successful', there is no guarantee that such methods would work with all athletes, especially those who have a greater S&C training age. This again confirms the need to undertake regular fitness testing in order to determine the effectiveness of training interventions.

AUTHORS' BIOGRAPHIES

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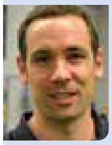

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