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Section: Case Study

Article Title: Case Study: Muscle Atrophy, Hypertrophy and Energy Expenditure of a Premier League Soccer Player During Rehabilitation From ACL Injury

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Case Study: Muscle atrophy, hypertrophy and energy expenditure of a premier league soccer player during rehabilitation from ACL injury

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Abstract

Maintaining muscle mass and function during rehabilitation from anterior cruciate ligament (ACL) injury is complicated by the challenge of accurately prescribing daily energy intakes aligned to energy expenditure. Accordingly, we present a 38-week case study characterizing whole body and regional rates of muscle atrophy and hypertrophy (as inferred by assessments of fat free mass from DXA) in a professional male soccer player from the English Premier League. Additionally, in week 6 we also quantified energy intake (via the remote food photographic method) and energy expenditure using the doubly labeled water method. Mean daily energy intake (CHO: 1.9-3.2, Protein: 1.7-3.3 and Fat: 1.4-2.7 $g.kg^{-1}$) and energy expenditure was 2765 ± 474 and 3178 $kcal.d^{-1}$ respectively. In accordance with an apparent energy deficit, total body mass decreased by 1.9 kg during week 1-6 where FFM loss in the injured and non-injured limb was 0.9 and 0.6 kg, respectively, yet, trunk FFM increased by 0.7 kg. In weeks 7-28, the athlete was advised to increased daily CHO intake (4-6 $g.kg^{-1}$) to facilitate an increased daily energy intake. Throughout this period, total body mass increased by 3.6 kg (attributable to a 2.9 and 0.7 kg increase in fat-free and fat mass, respectively). Our data suggest it may be advantageous to avoid excessive reductions in energy intake during the initial 6-8 weeks post-ACL surgery so as to limit muscle atrophy.

Key Words: carbohydrate, protein, knee, doubly labeled water

Introduction

Anterior cruciate ligament (ACL) injuries are a troublesome and potentially serious injury in soccer that often require surgical reconstruction (Brophy et al., 2012). After ACL reconstruction, an athlete's return to play time is reported to range from 16 to 52 weeks (Zaffagnini et al., 2014; Waldén et al., 2016), with factors affecting the length of recovery including concomitant damage (e.g. chondral defect or posterolateral corner damage) and achieving necessary exit criteria as part of the rehabilitation program (e.g. strength, power, range of motion, biomechanics and load tolerance) (Rue et al., 2011; Mithoether & Della Villa, 2012; Kyritsis et al., 2016; Dos'Santos et al., 2018). It is noteworthy, however, that a longer recovery time is associated with a reduced risk of reinjury (Nagelli & Hewitt, 2017; Grindem et al., 2016). A lengthy rehabilitation period typically consists of a gradual transition through different loading phases. Such phases are likely subject to different energy requirements and hence, nutritional recommendations should therefore be tailored to each phase (Milsom et al., 2014).

In the initial post operation recovery phase, the athlete is sometimes only partly mobile or completely immobile at the knee joint (Grant, 2013). This severely restricts the use of the muscle groups in the lower limbs and results in a period of muscle disuse. Under such circumstances, there is a progressive loss of fat-free mass (FFM) (Wall et al., 2013), a decline in functional strength (White et al., 1984), a reduction in (local) metabolic rate (Haruna et al., 1994), a decline in insulin sensitivity and increased local fat deposition (Richter et al., 1989).

In a previous case study by our group, we documented the rehabilitation of an English Premier League soccer player recovering from ACL surgery and observed a whole body FFM loss of 5.8 kg in the first 8 weeks of rehabilitation (Milsom et al., 2014). During this period, we found it difficult to provide accurate daily macronutrient and energy intake recommendations owing to the lack of knowledge regarding daily energy expenditure.

Additionally, loss of FFM in the trunk accounted for 3.8 kg of the whole body loss of FFM, thus highlighting the necessity to maintain a contractile stimulus to the non-injured muscle groups.

With this in mind, the aim of the present case-study was to quantify daily energy intake and expenditure (using the doubly labeled water method) during a 7-day training micro-cycle occurring 6 weeks after surgery i.e. a time when the athlete may be particularly susceptible to muscle atrophy. Additionally, we also present whole body and regional changes in body composition during the 38-week rehabilitation period.

Presentation of the Player

The player is a 26-year old male professional soccer player who is internationally capped and currently competing in the English Premier League. At the time of injury, the player's physical characteristics were as follows: age, 23 years old; body mass, 77 kg; height 179 cm. The player had been a full-time professional player since age 18 and had therefore been engaged in daily structured soccer-specific training for 5+ years. He has previously had 2 lateral meniscus tears (both knees) with the current injured knee and the uninjured knee at 4 and 3 years prior to this current injury, respectively. The player's muscle injuries were limited to 1 right hamstring tear at 1 year prior to injury. At the time of injury, the athlete was engaged in daily field-based soccer-specific training, 3 resistance-training sessions per week (1 focusing on lower limbs and 2 focusing on upper limbs) and 1-2 competitive games per week. The player had a training history of at least 2 resistance sessions per week (both primarily focusing on the lower limbs) for ~7 years. The player presented with a total rupture of the ACL ligament in his left knee. The injury occurred during a *landing motion* towards the end of a 1st team training session on the club's grass pitches. Surgery was performed 6 days after injury occurrence and involved surgical ligament reconstruction using a graft from the ipsilateral patella tendon to replace the damaged ACL. The player was not immobilized at any point during the rehabilitation although he spent 6 days post operation non-weight bearing on his injured limb.

Overview of Athlete Assessments

As part of the club's regular monitoring processes, a whole body fan beam dual-energy X-ray absorptiometry (DXA) measurement scan was performed at 6 days prior to injury (referred to as time-point 0 on Figures 1 and 2). Subsequent DXA scans were performed at 6, 12, 18, 28 and 38 weeks following surgery. All scans were performed at the same time of day (approximately 1 h within waking) and in a rested and fasted state (Nana et al., 2012, 2013). The time periods of DXA assessment were chosen based on our previous case-study account (Milsom et al., 2014) so as to allow for comparisons of changes in body composition within a similar time-scale (additionally these time-points also corresponded to DXA assessments of the rest of playing squad). Energy expenditure was determined during week 6 via the doubly labeled water (DLW) method as outlined by Anderson et al. (2017a). Week 6 was chosen due to it being the earliest time point possible at which the study specifics could be set up (e.g. availability of DLW and ethical approval). Energy and macronutrient intakes were also reported in week 6 as assessed by a combination of the remote food photographic method, 7-day food diaries and daily 24 h recalls (Anderson et al. 2017a,b). The lead author performed all 24 h recalls in the morning of each day when the player arrived at the club's training ground. Throughout the specific assessment week, the player's 'typical day' started at 08:30 and consisted of upper body cardiovascular work (08:30: 4x4 minutes interval work), breakfast (09:00 am), electrotherapy (09:30 am: electrical stimulation of the lower injured limb), lower limb strength training (10:30 am: see Table 1), lunch (12:00 pm), upper limb strength training or upper body cardiovascular work (13:00 pm: see Table 1: 4x4 minutes interval work), core training (14:00 pm: body weight and weighted isotonic and isometric exercises), hydrotherapy

(14:30 pm: knee mobility, proprioception and abdominal strength), soft tissue therapy (15:00 pm: directed relative to clinical presentation) and physiotherapy (15:30 pm: global treatment addressing knee mobility comorbidities) concluding at approximately 4 pm. The athlete engaged in this pattern of activity from Monday-Saturday during the week with Sunday (representative of Day 5 in Table 2) corresponding to a non-training day. The study was conducted according to the requirements of the Declaration of Helsinki and was approved by the university ethics committee of Liverpool John Moores University.

Quantification of Daily Energy Intake, Distribution and Energy Expenditure During the Weekly Micro-cycle

On the basis of a reduced daily loading pattern when compared to normal training, during weeks 1-6 the player was advised to adhere to a reduced CHO (3 $g.kg^{-1}$), high protein (2.5-3 $g.kg^{-1}$) and moderate fat intake (1.5 $g.kg^{-1}$) in an attempt to achieve daily energy intakes ranging from 2500-3000 $kcal.d^{-1}$. An overview of the players' reported energy and macronutrient distribution during week 6 is presented in Table 2. Despite the player being advised to adopt a balanced approach to feeding (especially in relation to adopting an even distribution of protein feeding of 30-40 g at main meals and snacks; Areta et al. 2013; Wall et al. 2015; Tipton, 2015; Dirks et al. 2018), it was evident that the player adopted a skewed approach to feeding where energy and macronutrients were consumed in a hierarchical order of dinner >> lunch >> breakfast >> snacks. Nonetheless, the player was successful in achieving the prescribed daily energy intake on 4 of the 7 days where mean daily energy intake was 2765 ± 474 $kcal.d^{-1}$. Additionally, mean daily energy expenditure during this period (as assessed from DLW) equated to 3178 $kcal.d^{-1}$, thus highlighting that the player was likely in energy deficit on 6 of the 7 days.

Anthropometric Developments During the Rehabilitation

In accordance with the energy deficit documented above, total body mass decreased by 1.9 kg during weeks 1-6, inclusive of a loss of 0.6 kg and 1.2 kg of FFM and fat mass, respectively. It is noteworthy that during this period the major contributor to FFM loss was through the player's injured and non-injured limbs by 0.9 kg and 0.6 kg, respectively (see Figure 2). There was also small loses of 0.1 and 0.4 kg in both injured and non-injured injured and non-injured leg fat mass, respectively. Despite the reduction in FFM of the lower limbs, trunk FFM increased by 0.7 kg and trunk fat mass decreased by 0.7 kg (see Figure 2), likely due to the upper body strength training programme that was commenced from week 2.

During weeks 7-38, the player was advised to increase his daily energy intake, largely via increasing his daily CHO intake to 4-6 $g.kg^{-1}$. Whilst we did not assess daily energy and macronutrient intake during this time period, it was evident that the player was in positive energy balance given the changes in body mass and composition observed in Figure 1 and 2. Indeed, during weeks 7-28, FFM increased in the lower limbs (1.0 and 1.0 kg in the injured and non-injured limb, respectively) and trunk (0.7 kg), collectively contributing to an increase in whole body FFM of 2.9 kg (though it is acknowledged that this may also be in due part to glycogen storage associated with increased daily CHO intakes, Bone et al., 2017). During this time, whole body fat mass also increased by 0.7 kg. From weeks 28-38, FFM in the injured and non-injured leg reduced by 0.6 and 0.7 kg, respectively. It is noteworthy that the player returned to competition in week 31 with an improved anthropometrical profile compared to pre-injury.

Reflections

Maintaining muscle mass and function during rehabilitation from ACL injury is complicated by the challenge of accurately prescribing daily energy intakes aligned to energy expenditure. Indeed, in a previous case-study study by our group (Milsom et al. 2014), we observed a whole body FFM loss of 5.8 kg (3.8 kg of which was from the trunk) in the initial 8 weeks after surgery. Accordingly, the specific aim of the present case-study was to quantify energy expenditure (via the DLW method) during a training micro-cycle where the athlete may be particularly susceptible to muscle atrophy i.e in the initial 6-8 weeks after surgery. Additionally, we also quantified body composition changes (via DXA) during the 38-week rehabilitation period.

In contrast to our previous study, the athlete studied here was not immobilized at any time-point during the rehabilitation period. Given the large atrophy observed previously (where daily energy intake was <2000 kcal.d^{-1} and no form of upper body resistance training was performed during the initial 8 weeks after surgery), the initial 6-week intervention detailed here focused on achieving higher daily energy intakes (i.e. 2500-3000 kcal.d^{-1}) as well as incorporating 3 upper body resistance training sessions per week. In accordance with no specific immobilization phase, the athlete was also able to complete 5 lower body strength-training sessions per week. As such, the combination of increased daily energy intake and higher absolute loading of both the trunk and lower limbs was apparently successful in reducing rates of whole body muscle atrophy (-0.1 versus -0.73 kg per week), injured limb atrophy (-0.15 versus -0.18 kg per week) and trunk muscle atrophy (+0.1 versus -0.48 kg per week) when compared to the athlete studied by Milsom et al. (2014). When taken together, these data suggest it may be advantageous to avoid excessive reductions in energy intake as well as maintaining a contractile stimulus to the non-injured muscle groups.

In an attempt to better understand the energy requirements during the early phase of rehabilitation, we also quantified energy expenditure using the DLW method. In week 6, we observed a mean daily energy expenditure of 3178 kcal.d^{-1} and a mean daily energy intake of 2765 ± 474 kcal.d^{-1}. Examination of daily energy intake data also demonstrated that the athlete was likely in energy deficit on 6 of the 7 days of this specific micro-cycle. In relation to the specific player studied here and the daily loading patterns, our data therefore suggest mean daily energy intakes of approximately 3000-3500 kcal.d^{-1} may have been required to maintain energy balance during the early stages of rehabilitation. We acknowledge, however, that additional assessments of energy expenditure and intake during week 1-5 would also have been beneficial so as to provide further inferences on daily energy balance.

It is noteworthy that the energy expenditure observed here was only 300 kcal.d^{-1} less than that observed in outfield players from the same team (as studied during a 2 game per week microcycle; Anderson et al., 2017a) but yet, 300 kcal.d^{-1} more than a goalkeeper from the same team (Anderson et al., 2018). Despite the reduced absolute intensity of training when compared with outfield players, it is therefore apparent that the increased duration and frequency of daily activities typically completed during rehabilitation (e.g the athlete performed rehabilitation activities in both the morning and afternoon) may manifest as a total daily energy requirement that is comparable to outfield players. Accordingly, from week 6 onwards the player was advised to increase daily energy intake (via increasing daily CHO intake to 4-6 g.kg) in an attempt to promote muscle hypertrophy. In this regard, the presentation of body composition data in Figure 1 and 2 suggest that the increased daily energy intake in accordance with maintaining high daily protein intake and increased whole body loading (see Table 1) was successful in inducing muscle hypertrophy in the trunk and both the injured and non-injured limbs. It is acknowledged that additional assessments of energy expenditure could also be made at various stages of the rehabilitation phase so as to further aid accurate energy and macronutrient prescriptions.

As with all case-study accounts, the limitations are that only one player was studied whilst under a specific program that was underpinned by the philosophy of the performance and medical department within the club of investigation. Whilst this player was subjected to a similar rehabilitation program and staffing base as the player studied by Milsom et al. (2014), there is a definitive need to also study the energy requirements of additional players from different teams during rehabilitation from long-term injuries. Such a collaborative effort will help to optimize nutritional interventions for injured athletes.

In summary, our data suggest that daily energy requirements during the initial 6 weeks of rehabilitation may be comparable to that of outfield players, likely due to the increased duration of daily activities and the energetic cost of repairing injured tissues. It may therefore be advantageous to avoid excessive reductions in energy intake during the early rehabilitation period, begin loading of the injured limb as soon as possible and incorporate training activities that maintain a contractile stimulus to the non-injured muscle groups. Whilst we acknowledge that any nutritional strategy should be tailored to the specific athletic situation, it is hoped that the publication of these data will prompt further reflection of the loading patterns and nutritional strategies that can help achieve successful rehabilitation from long term injury.

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The study was designed by LA, GLC, BD and JPM and data were collected and analysed by LA, MK, DR, JM, CH and JRS; data interpretation and manuscript preparation were undertaken by LA, GLC, MK, DR, JM, BD and JPM. All authors approved the final version of the paper.

References

Anderson, L., Close, G.L., Morgans, R., Hambly, C., Speakman, J.R., Drust, B., & Morton, J.P. (2018). Case Study: Assessment of energy expenditure of a professional goalkeeper from the English premier league using the doubly labeled water method. *International Journal of Sports Physiology and Performance, 14,* 1-13.

Anderson, L., Orme, P., Naughton, R.J., Close, GL., Milsom, J., Rydings, D., … Morton, J.P. (2017a). Energy intake and expenditure of professional soccer players of the English Premier League: evidence of carbohydrate periodization. *International Journal of Sports Nutrition and Exercise Metabolism, 27,* 228-238.

Anderson, L., Naughton, R.J., Close, G.L., Di Michele, R., Morgans, R., Drust, B., & Morton, J.P. (2017b). Daily distribution of macronutrient intakes of professional soccer players from the English Premier League. *International Journal of Sports Nutrition and Exercise Metabolism, 28,* 1-18.

Areta, J.L., Burke, L.M., Ross, M.L., Camera, D.M., West, D.W., Broad, E.M., Coffey, V.G. (2013). Timing and distribution of protein ingestion during prolonged recovery from resistance exercise alters myofibrillar protein synthesis. *The Journal of Physiology, 591,* 2319-2331.

Bone, J.L., Ross, M.L., Tomcik, K.A., Jeacocke, N.A., Hopkins, W.G., & Burke, L.M. (2017). Manipulation of muscle creatine and glycogen changes Dual X-ray absorptiometry estimates of body composition. *Medicine & Science in Sports & Exercise, 49,* 1029-1035.

Brophy, R.H., Schmitz, L., Wright, R.W., Dunn, W.R., Parker, R.D., Andrish, J.T., … Spindler, K.P. (2012). Return to play and future ACL injury risk following ACL reconstruction in soccer athletes from the MOON group. *American Journal of Sports Medicine, 40,* 2517-2522.

Dirks, M.L., Wall, B.T., & van Loon, L.J.C. (2018). Interventional strategies to combat muscle disuse atrophy in humans: focus on neuromuscular electrical stimulation and dietary protein. *Journal of Applied Physiology, 25,* 850-861.

Dos'Santos, T., Thomas, C., Comfort, P., & Jones, P.A. (2018). The effects of angle and velocity on change of direction biomechanics: an angle-velocity trade off. *Sports Medicine, 48,* 2235-2253.

Grindem, H., Snyder-Mackler, L., Moksnes, H., Engebretsen, L., & Risberg, M.A. (2016). Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Oslo ACL cohort study. *British Journal of Sports Medicine, 50, 804-808.*

Haruna, Y., Suzuki, Y., Kawakubo, K., Yanagibori, R., & Gunji, A. (1994). Decremental reset in basal metabolism during 20-days bed rest. *Acta Physiologica Scandinavica Supplementum, 616,* 43-49.

Kyritsis, P., Bahr, R., Landreau, P., Miladi, R., & Witvrouw, E. (2016). Infographic. Avoid ACL graft rupture. Meet discharge criteria. *British Journal of Sports Medicine, 50,* 952.

Milsom, J., Barreira, P., Burgess, D.J., Iqbal, Z., & Morton, J.P. (2014). Case study: Muscle atrophy and hypertrophy in a premier league soccer player during rehabilitation from ACL injury. *International Journal of Sports Nutrition and Exercise Metabolism, 24,* 543-552.

Mithoefer, K., & Della Villa, S. (2012). Return to sports after articular cartilage repair in the football (soccer) player. *Cartilage, 3,* 575-625.

Nana, A., Slater, G.J., Hopkins, W.G., & Burke, L.M. (2012). Effects of daily activities on dual-energy X-ray absorptiometry measurements of body composition in active people. *Medicine and Science in Sports and Exercise, 44,* 178-185.

Nana, A., Slater, G.J., Hopkins, W.G., & Burke, L.M. (2013). Effects of exercise sessions on DXA measurements of body composition in active people. *Medicine and Science in Sports and Exercise, 45,* 178-185.

Nagelli, C.V., & Hewett, T.E. (2017). Should return to sport be delayed until 2 years after anterior cruciate ligament reconstruction? Biological and functional considerations. *Sports Medicine, 47,* 221-232.

Richter, E., Kiens, B., Mizuno, M., & Strange, S. (1989). Insulin action in human thighs after one-legged immobilization. *Journal of Applied Physiology, 67,* 19-23.

Rue, J.P., Kilcoyne, K., Dickens, J., & Kluk, M. (2011). Diagnosis and treatment of injuries to the posterolateral ligament complex. *Journal of Knee Surgery, 24,* 143-150.

Tipton, K.D. (2015). Nutritional support for exercise-induced injuries. *Sports Medicine, 45,* 93-104.

Waldén, M., Hägglund, M., Magnusson, H., & Ekstrand, J. (2016). ACL injuries in men's professional football: a 15 year prospective study on time trends and return-to-play rates reveals only 65% of players still play at the top level 3 years after ACL rupture. *British Journal of Sports Medicine, 50,* 744-750.

Wall, B.T., Dirks, M.L., & Van Loon, L.J.C. (2013). Skeletal muscle atrophy during short-term disuse: implications for age related sarcopenia. *Ageing Research Reviews, 12,* 898-906.

Wall, B.T., Morton, J.P., & van Loon, L.J. (2015). Strategies to maintain skeletal muscle mass in the injured athlete: nutritional considerations of exercise mimetics. *Eur J Sports Sci, 15,* 53-62.

White, M., Davies, C., & Brooksby, P. (1984). The effects of short-term voluntary immobilization on the contractile properties of the human tricpe surae. *Quarterly Journal of Experimental Physiology and Cognate Medical Services, 69,* 685-691.

Zaffagnini, S., Grassi, A., Marcheggiani Muccioli, G.M., Tsapralis, K., Ricci, M., Bragonzoni, L., … Marcacci, M. (2014). Return to sport after anterior cruciate ligament reconstruction in professional soccer players. *The Knee, 21,* 731-735.

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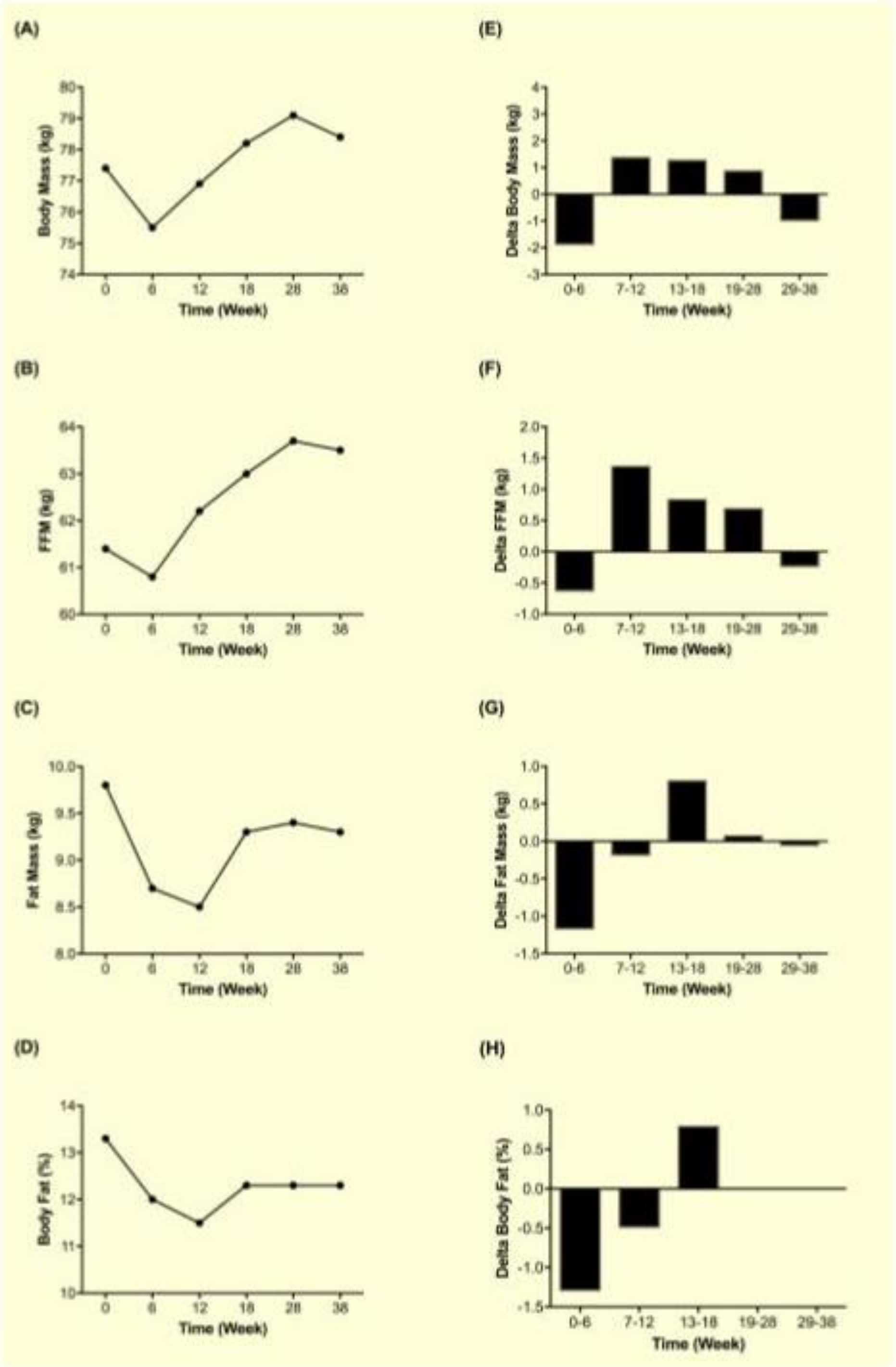

Figure 1. Changes in total (A) body mass, (B) FFM, (C) fat mass and (D) body fat. Changes in (E) body mass, (F) FFM, (G) fat mass and (H) body fat expressed as delta change during the specific period highlighted. FFM = Fat-free mass

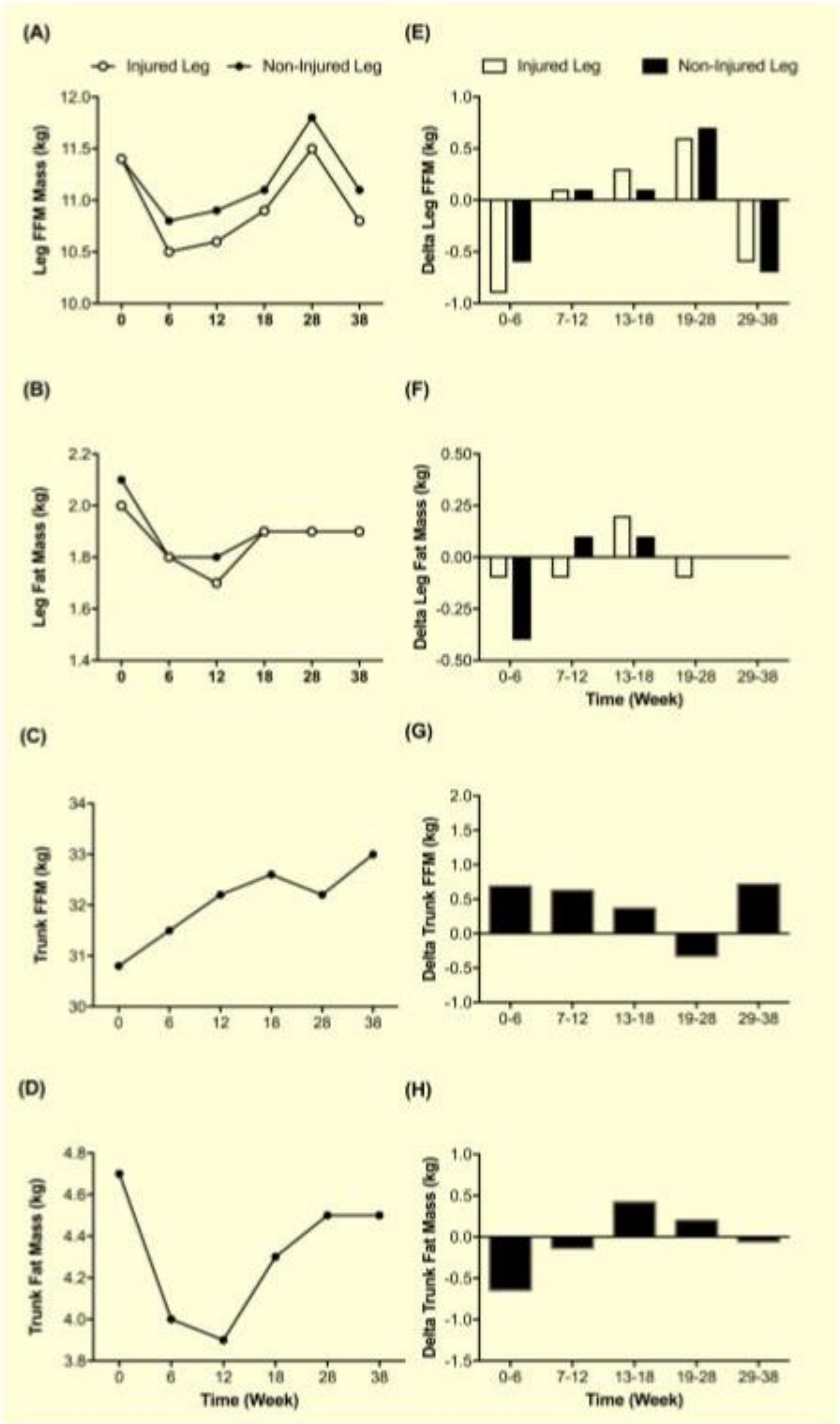

Figure 2. Changes in total (A) leg FFM, (B) leg fat mass, (C) trunk FFM and (D) trunk fat mass throughout the rehabilitation. Changes in (E) leg FFM, (F) leg fat mass, (G) trunk FFM and (H) trunk fat mass expressed as delta change during the specific period highlighted. FFM = Fat-free mass.

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Table 1. An overview of the Lower and Upper body Strength and Conditioning Programme alongside the Pitch based rehabilitation

		Lower Body Gym Programme		
Goal	**Muscle endurance and maintenance on uninjured limb**	**Hypertrophy**	**Strength with introduction of powerful actions**	**Power, speed and maintenance of strength**
Weeks	2-8	9-14	15-20	21-27
Frequency/ week	5	5	3	2-3
Rep range	8-12	8-12	4-8	4-6
Sets/ session	20-30	30-40	30-40	30-40
Exercise selection	2 sessions, performed on alternate days *Session 1* *All on uninjured limb 2xPW* 1xOKC and 1xCKC exercise for quadriceps and hamstrings, 1 xCKC for the calf muscles *Session 2* *Performed with both limbs 3x Per Week* 3xCKC hip extension exercises, 1xOKC exercise for hip flexion, extension and adduction, 2xOKC exercises for hip abduction.	2 sessions, performed on alternate days *Session 1* *Performed with both limbs 3xPW* 1xOKC and 1xCKC exercise for quadriceps and hamstrings, 1 xCKC for the calf muscles *Session 2* *Performed with both limbs 2xPW* 3xCKC hip extension exercises, 1xOKC exercise for hip flexion, extension and adduction, 2xOKC exercises for hip abduction.	1xOKC and 4xCKC exercise for quadriceps (2xLow movement speed/high load 1xMaximal isometric and 1xBallistic exercise) 1xOKC and 1xCKC exercises for the hamstrings 1xCKC for the calf muscles 1xCKC hip extension exercises 1xOKC exercise for hip flexion, extension, abduction and adduction.	1xOKC and 4xCKC exercise for quadriceps (1xLow movement speed/high load 3xBallistic/Plyometric exercises), 1xOKC and 1xCKC exercises for the hamstrings 1xCKC for the calf muscles 1xCKC hip extension exercises 1xOKC exercise for hip flexion, extension, abduction and adduction.
		Upper Body Gym Programme		
Goal	**Strength**	**Strength**	**Strength/Power**	**Strength/Power**
Weeks	2-8	9-12	13-18	19-24
Frequency/ week	3	3	2-3	2-3
Rep range	6-8	6-8	4-6	4-6
Sets/ session	24	24	18-24	18-24
Exercise selection	Bench Press Bench Pull Cable Pulldown Cable Raise Chin Up Rear Fly	Bench Press Bench Pull Cable Pulldown Cable Raise Chin Up Rear Fly	Ballistic Press Up MB Throws Pull Up Cable Rear Fly Cable Press TRX Row	Ballistic Press Up MB Throws Pull Up Cable Rear Fly Cable Press TRX Row
		Pitch Programme		
Goal	**Gait Restoration and Endurance**	**Football Specific Movements and Endurance**	**Training and Match Play Simulation**	**Team Training**
Weeks	16-19	20-23	24-27	28-31
Frequency/ week	2-3	2-3	3-5	4-5
Volume of Training	Low	Moderate	Hard	
Intensity of Effort	30-60%	50-80%	80-100%	
Complexity of Tasks	Easy	Moderate	Hard	
No. of Sessions	11	8	15	13
Duration/ session (minutes)	40 ± 10	56 ± 5	75 ± 24	46 ± 17
Distance/ session (m)	3700 ± 1191	4363 ± 477	5728 ± 2602	3438 ± 1429
High speed distance/ session (m)	218 ± 282	384 ± 170	373 ± 359	104 ± 137

PW = Per Week, MB = Medicine Ball, OKC = Open Kinetic Chain, CKC = Close Kinetic Chain

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Table 2. Total daily and distribution of energy and macronutrient intakes across the weekly micro-cycle

	Day 1	2	3	4	5	6	7	Average ± SD
Energy (kcal)	**3626**	**3037**	**2382**	**2925**	**2417**	**2679**	**2286**	**2765 ± 474**
Energy (kcal.kg^{-1}	**59.6**	**49.9**	**39.2**	**48.1**	**39.7**	**44.1**	**37.6**	**45.5 ± 7.8**
Breakfast (g)	441	461	519	450	463	838	450	517 ± 144
Morning Snack	134	80	-	-	21	119	-	89 ± 50
Lunch (g)	1031	684	751	665	1119	911	962	875 ± 177
Afternoon Snack	223	385	688	405	-	336	249	378 ± 167
Dinner (g)	1798	1446	424	1405	813	475	452	973 ± 568
Evening Snack (g)	-	-	-	-	-	-	173	173 ± 0
CHO (g)	**218**	**146**	**172**	**239**	**203**	**150**	**141**	**181 ± 39**
CHO (g.kg^{-1})	**2.9**	**1.9**	**2.3**	**3.2**	**2.7**	**2.0**	**1.9**	**2.4 ± 0.5**
Breakfast (g)	0.8	0.8	17	0.9	63	32	0.9	16 ± 24
Morning Snack	33	5	-	-	2.7	7.4	-	12 ± 14
Lunch (g)	58	34	66	21	55	62	77	53 ± 19
Afternoon Snack	22	48	75	28	-	29	29	39 ± 20
Dinner (g)	105	58	14.2	179	83	19.5	8	67 ± 62
Evening Snack (g)	-	-	-	-	-	-	27	27 ± 0
Protein (g)	**242**	**245**	**192**	**210**	**128**	**205**	**182**	**201 ± 40**
Protein (g.kg^{-1})	**3.3**	**3.2**	**2.5**	**2.8**	**1.7**	**2.7**	**2.4**	**2.7 ± 0.5**
Breakfast (g)	54	34	35	34	17	56	34	38 ± 13
Morning Snack	0	5.3	-	-	1.3	7.9	-	4 ± 4
Lunch (g)	71	66	79	51	90	57	60	68 ± 13
Afternoon Snack	19.8	7.4	30	27	-	28	20	22 ± 8
Dinner (g)	97	132	48	98	19.7	56	50	72 ± 39
Evening Snack (g)	-	-	-	-	-	-	18	18 ± 0
Fat (g)	**201**	**167**	**108**	**129**	**125**	**144**	**114**	**141 ± 33**
Fat (g.kg^{-1})	**2.7**	**2.2**	**1.4**	**1.7**	**1.7**	**1.9**	**1.5**	**1.9 ± 0.4**
Breakfast (g)	24	36	35	35	17.5	55	35	34 ± 12
Morning Snack	0	4.5	-	-	0.7	6.7	-	3 ± 3
Lunch (g)	59	32	21	42	61	50	48	45 ± 14
Afternoon Snack	6.6	16.6	32	17.4	-	13.3	6.7	15 ± 9
Dinner (g)	111	78	19.6	35	46	19.6	25	48 ± 35
Evening Snack (g)	-	-	-	-	-	-	0	0 ± 0