

# SUPPLEMENTARY MATERIAL

SM\_1\_Details of the rehabilitation algorithm

## Details of the rehabilitation algorithm

### 6. RTA-PHASE (ALGORITHM)

#### 6.1. ENTRANCE IN ALGORITHM: LEVEL OF PHYSIOTHERAPY

##### Level of physiotherapy:

The "Level of Physiotherapy" is the initial phase for entry into the algorithm. The athlete remains in this phase until the acute symptoms have resolved and ankle-specific rehabilitation has begun (from level 1) after having passed the entry criteria for testing (AFS>40, 30 sec. weight-bearing, no signs of acute inflammation, walking without pain). This level aims to initiate undisturbed wound healing, achieving painlessness, and the restoration of a free range of motion (ROM). The initiation of undisturbed wound healing and painlessness is of paramount interest at this stage, as all forms of injury (tissue damage) through inflammation lead to immediate changes in neurosignature, especially movement behaviour, which, if unrestored, will lead to long-term chronic impairments.<sup>69</sup> Targeted physiotherapeutic interventions, especially manual therapy, bear the potential to positively influence neurosignature at an early stage and should be the predominant element of early functional rehabilitation in the acute and sub-acute phase. In addition, manual therapy shows positive effects in preventing restrictions in ROM, especially dorsal extension.<sup>37</sup> Clinical guidelines recommend that a full passive range of motion should be restored two weeks after LAS.<sup>4,5</sup> There is strong evidence for the use of several manual therapy procedures (lymphatic drainage, active / passive soft tissue and joint mobilisation, anterior-posterior talar mobilisation) to reduce swelling, improve painfree movement and normalize gait pattern. Furthermore, current clinical practice guidelines (CPG) find weak evidence for the use of cryotherapy, diathermy, lower laser and NSAR and no evidence for using ultrasound.<sup>9</sup>

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32 **Progression from Level of Physiotherapy to Level 1:**

33 *Level of Physiotherapy: Aims*

34 The objective is to ensure assessment for Level 1 entry tests.

35 *Level of Physiotherapy: Progression (entrance) criteria and considerations*

36 The following (progression) criteria apply for the release of Level of Physiotherapy to perform  
37 level 1 testing:

- 38     ▪ AFS > 40/100
- 39     ▪ 30 sec. weight bearing
- 40     ▪ No signs of inflammation
- 41     ▪ Walking without pain

42 The decision to start an active rehabilitation program remains challenging. Therefore, the  
43 athlete's readiness to safely execute functional performance tests must in itself be tested.<sup>29</sup>  
44 Therefore, specific criteria to start functional performance tests must be fulfilled: 40/100 points  
45 in the AFS describe the benchmark for performing ADL within the next two weeks.<sup>36</sup> This is  
46 similar to the biomechanical loads of ankle-specific rehabilitation that begins shortly thereafter.  
47 The athlete is expected to be able to stand on one leg for 30 seconds without pain, as the level  
48 1 entry tests are single-leg weight-bearing tests. In addition, the athlete should show no signs  
49 of inflammation and should be able to walk without pain.<sup>14</sup> Starting the testing and therapy level  
50 too early negatively influences the neurosignature and increases the risk of maladaptive  
51 movement behaviour (relieving posture, compensation) in rehabilitation training right from the  
52 start.

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54 **6.2. PROGRESSION WITHIN THE RTA-PHASE**

55 **Level 1 (Proprioception)**

56 *Level 1: Aims*

57 The aim of level 1 is the early initiation and training of sensorimotor functions without  
58 biomechanical impacts on the ligament structures. In addition, level 1 prepares athletes for  
59 running (milestone) of the subsequent level (tab.1).

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61 *Level 1: Progression (entrance) criteria and considerations*

62 To enter training level 1, the athlete is required to pass the following criteria:

- 63     ▪ AFS-Score >40/100
- 64     ▪ Passing the clinical examination
- 65     ▪ Passing the performance tests (mod. Stork Balance Test; Y-Balance Test)

Aim / Focus	Tests	Progression criteria	Explanation choice of tests	Methodological considerations	Training exercises	Explanation choice of training exercises
<b>Proprioception</b>	Ankle Function Score	AFS > 40/100	<ul style="list-style-type: none"> <li>- Integration of questionnaires recommended<sup>11,24,38,70</sup></li> <li>- Is an evaluative rather than discriminative instruments<sup>71</sup></li> <li>- simple instrument, recommend for daily practice<sup>72</sup></li> <li>- additional as a prognostic tool and progression control<sup>36,37</sup></li> </ul>	<ul style="list-style-type: none"> <li>- AFS &gt;40 ensures the ability of Activities of daily living ADL<sup>36</sup></li> <li>- ADL activities corresponds to biomechanical loads of level 1 training exercises</li> </ul>	Weight-bearing in progression model; principles of motor learning (e.g. external focus strategies) <sup>73</sup>  Stationary bicycle  Ankle muscle (peroneal) strength training  Crosstrainer  Alter G	Low biomechanical impact on ligamentous structures  Only vertical loading  Muscle pump (lymphatic) Closed chain exercise, plantarflexion, improves collagen synthesis (keeping low impact)  Adequate strength is necessary for normal movement patterns <sup>61</sup>  Prepares for running
	Clinical examination	ADT / TLT  Swelling  ROM  MFT (4/5)	<ul style="list-style-type: none"> <li>- <b>Clinical control</b> (standardised, individual), ensures reliable assessments over time</li> <li>- Sensitivity (0.50-0.96); Specificity (0.67-1.00)<sup>15,38,51,53</sup></li> <li>- the assessment of ankle joint <i>swelling</i> is advocated<sup>17</sup></li> <li>- recommend in clinical practice guidelines<sup>8</sup></li> </ul> ROM  <ul style="list-style-type: none"> <li>- Manual <b>muscle testing</b> is standard test of muscle strength<sup>28,39,40</sup></li> </ul>	<ul style="list-style-type: none"> <li>- recommend after day 5 post injury<sup>38</sup>, corresponds to this point of time;</li> <li>- grading system ensures standardised assessment over time</li> <li>- ROM in ant. direction is required for test and training<sup>41,42</sup></li> <li>- ROM should be resumed first, before functional rehabilitation starts<sup>38</sup></li> <li>- muscular activation of the peroneus muscles crucial for weight-bearing (activation, stability)</li> <li>- 4/5 ensures strength against resistance (corresponds to stance stability)</li> <li>- peroneus muscles may be impaired after ankle sprain injury<sup>49</sup></li> </ul>		
	Proprioception tests	Mod. Stork Balance Test	<ul style="list-style-type: none"> <li>- Static test; sensory<sup>42</sup></li> <li>- established in lower limb rehabilitation</li> </ul>	<ul style="list-style-type: none"> <li>- low impact test („low load“)</li> <li>- stance ability prior tested (30 sec. single leg stance)</li> <li>- MFT 4/5 ensures the ability for stable stance (muscle activation)</li> </ul>		

		Y-Balance Test	<ul style="list-style-type: none"> <li>- dynamic test; motor-control<sup>42</sup></li> <li>- recommend and established in rehabilitation</li> <li>- strong reliability<sup>41,73,74,75</sup></li> <li>- good validity<sup>41,75</sup></li> </ul>	<ul style="list-style-type: none"> <li>- corresponds to demands of level 1 training exercises</li> <li>- full ROM required in ant. direction → prior manually compiled during physical therapy<sup>41,76</sup></li> <li>- more dynamic and load compared to Stork Balance Test (progression)<sup>76,77,78</sup></li> </ul>		
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71 **Level 2 (running)**

72 *Level 2: Aims*

73 The aim of level 2 is to start running (milestone) and a progression in jumping skills (tab.2).

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75 *Level 2: Progression (entrance) criteria and considerations*

76 The athlete must pass the following criteria to enter training level 2:

- 77     ▪ AFS-Score >60/100
- 78     ▪ Passing the clinical examination
- 79     ▪ Passing the performance tests (Heel Rise Test; qualitative running analysis)

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Aim / Focus	Tests	Progression criteria	Explanation choice of tests	Methodological considerations	Training exercises	Explanation choice of training exercises
<b>Running</b>	Ankle Function Score	AFS > 60/100	- See above.	- 60 points is nearly the middle of 40 and 75 (empirical experienced) - 40 means low impact (ADL) - 75 means high impact and „recovered“ <sup>47,71</sup>	Linear running  Progression in running speed  Start with jumps (progression)	long stance phase (less reactive impacts)  prepares for more dynamic reactive training skills in level 3  prepares for jump tests in level 3 Prepares for more dynamic and reactive training exercises in level 3
	Clinical examination	ADT / TLT	- control of laxicity - established tests in clinical settings and progression control <sup>7,28</sup>	- ensures stability (no laxicity) during running in landing and propulsion phase (no talus translation)		
		Swelling ROM	- reaction indicated through increase in effusion (→ control)			
		MFT	- ensures muscular stability surround the ankle joint	- more strength is needed for stance phase during running (Level 2) compared to weight bearing stance phase (Level 1)		
	Heel Rise Test (HRT)	Heel Rise Test (LSI 90%)	- established test for lower limb (foot, ankle) rehabilitation <sup>62,79</sup> - established in rehabilitation protocols <sup>47</sup> - used as progression criteria <sup>62</sup> - test for endurance and strength of the calf muscle performance <sup>61,62,79,81</sup>	- calf muscle power impaired after injury  - HRT prior to running analysis (progression) - HRT assesses calf muscle isolated whilst running analysis assesses calf muscle in performance - calf muscles essential for movement like running / walking <sup>40,61,62</sup>		
	Running analysis	Running analysis	- recommend for lower limb injury (ACL) <sup>11</sup> - essential information about running rhythm <sup>11</sup> - Assessment of walking gait is endorsed following acute LAS <sup>15</sup>	- detectable deficits in HRT exclude from running analysis		

85 **Level 3 (jump ability)**

86 *Level 3: Aims*

87 The goal of this level is the progressive increase of linear running speeds under increasingly  
88 reactive aspects (short ground contact time) and the implementation of dynamic-reactive  
89 imprint patterns in both the frontal and sagittal planes (tab.3).

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91 *Level 3: Progression (entrance) criteria and considerations*

92 The athlete must pass the following criteria to transition to Level 3:

- 93     ▪ AFS > 75/100
- 94     ▪ Passing the clinical examination
- 95     ▪ Passing the performance tests (Side Hop Test (SHT); Triple Hop Test (THD))

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Aim / Focus	Tests	Progression criteria	Explanation choice of tests	Methodological considerations	Training exercises	Explanation choice of training exercises
<b>Jump performance ability</b>	Ankle Function Score	>75/100	See above. - cutoff point for being healed was defined as obtaining more than 75 points on a function score <sup>7</sup>	- >75/100 corresponds to full recovery <sup>71</sup> , corresponds to expected loads of training in level 3 (jumps, reactive impacts)	ladder training (short reactive impacts)  extensive intervall running	reactive stress promotes collagen synthesis (essential to this phase of healing) <sup>14</sup> Shift towards fore foot exercises  increased running speed forces short reactive dynamic GRF
	Clinical examination	ADT / TLT Swelling ROM	See above.	See above.		
	Side Hop Test (SHT)	Side Hop Test (LSI 90%)	- established test in ankle rehabilitation - highly recommend for ankle assessment <sup>28,82</sup> - good reliability ( $r > 0,85$ ); heightened sensitivity (77%) <sup>58</sup> - recommended as a RTP criterion <sup>83</sup> - assessments recommended for both frontal and sagittal plane <sup>83</sup>	- transition of „guided“ closed-chain exercises to dynamic reactive impacts in level 3 training exercises - SHT assesses reactive impacts - frontal plane prior to sagittal plane (LFTA in sagittal direction; talus translation) - test forces lateral stress to the joint <sup>28,83</sup>		
Triple Hop Test (THD)	Triple Hop Test (LSI 90%)	- reliability: 0.94-0.95 <sup>29</sup>	- isolated test in sagittal jump direction enforces explosive strength of the thigh: <sup>26</sup> Therefore begin with jump training in level 2 - frontal plane Test (SHT) prior to sagittal plane (THD) test (→ LFTA direction)			

102 **Level 4: jumps and rehabilitative athletic skills**

103 *Level 4: Aims*

104 Level 4 aims to train high-load football-specific athletic skills (sprinting, change of direction,  
105 cutting) (tab.4).

106 *Level 4: Progression (entrance) criteria and considerations*

107 To enter Level 4, the following testing criteria must be met:

- 108     ▪ AFS > 85/100
- 109     ▪ Passing the clinical examination
- 110     ▪ Passing the performance tests (Square Hop Test (SQHT), Crossover Hop for Distance  
111         (CHD), mod. 6 meters timed Crossover (mT6CH)

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Aim / Focus	Tests	Progression criteria	Explanation choice of tests	Methodological considerations	Training exercises	Explanation choice of training exercises
<b>Jump power performance / rehabilitation athletic skills</b>	Ankle Function Score	AFS > 85/100	See above.	<ul style="list-style-type: none"> <li>- 75/100 full recovery<sup>71</sup></li> <li>- 85/100 demonstrates further improvements (continuous progression)</li> </ul>	<p>Athletic skills</p> <p>Multidirectional movement pattern</p> <p>Sprinting</p>	<p>Level 3 short impacts (controlled)</p> <p>Level 4 high (running) load + cutting</p>
	Clinical examination	ADT / TLT  Swelling ROM	See above.	<ul style="list-style-type: none"> <li>- max. static plantarflexion ROM is essential for ball training in following RTS level. 39% of shoots exceed max. plantarflexion to the ankle joint<sup>68</sup></li> </ul>		
	Square Hop Test (SQHT)	Square Hop Test (LSI 90%)	<ul style="list-style-type: none"> <li>- assessment of both frontal and sagittal plane under controlled conditions</li> <li>- useful test for lower limb / ankle injury rehabilitation (Quelle)</li> <li>- good reliability (ICC of 0.90; SEM 1.40)<sup>83</sup></li> </ul>	<ul style="list-style-type: none"> <li>- assessment of both planes isolated under controlled conditions</li> <li>- while THD + SHT assess only one direction (level 3), SQHT assesses both directions simultaneously (progression to level 3 tests)</li> <li>- test reaktice on the fore foot (skills prior trained in level 3)</li> </ul>		
	Crossover Hop for Distance Test (CHD)	Crossover Hop for Distance Test (LSI 90%)	<ul style="list-style-type: none"> <li>- reliability: 0.85-0.96<sup>29</sup></li> <li>- established in lower limb rehabilitation</li> <li>- assessment of both frontal and sagittal plane under reduced controlled conditions compared to SQHT</li> </ul>	<ul style="list-style-type: none"> <li>- similar to THD with additional component (middle line) enforces further progression</li> <li>- high coordinative demands / motor control through landing task</li> <li>- jumps across the line enforces stress to the lateral ligaments</li> </ul>		
Mod. 6m timed Crossover Hop for Distance Test (mT6H)	Mod. 6m timed Crossover Hop for Distance Test (LSI 90%)	<ul style="list-style-type: none"> <li>- established test for lower limb rehabilitation<sup>56</sup></li> <li>- test of reactive impacts</li> <li>- additional time component</li> <li>- T6H reliability: 0.66-0.97<sup>29</sup></li> </ul>	<ul style="list-style-type: none"> <li>- mod. version: addition of a middle line</li> <li>- test modifications for specific needs suggested<sup>45</sup></li> <li>- further progression to CHD (additional time component)</li> <li>- final test both of the level and the entire rehabilitation progression</li> </ul>			

## **7. RTS Level**

### ***RTS-Level: Football-specific rehabilitation***

#### ***RTS-Level: Aims***

The RTS level aims to increase load progressively with football-specific ball training.

#### ***RTS-Level: Progression (entrance) criteria and considerations***

The entry criteria to the RTS level are defined as follows

- AFS > 95/100
- Passing the entire test battery
- Clinical clearance by PT

Entry into the RTS level requires an AFS>95/100 points, unrestricted clearance by clinical examination and passing the entire test battery.

#### ***Aims and Training Exercises RTS-Level:***

The goal of the RTS level is the gradual increase of football-specific training with the ball. We recommend a gradual, progressive approach. This should take into account the biomechanical impacts on the ligamentous apparatus.

Shinkai et al.<sup>67</sup> determined an average impact force of 1400 N, which can increase to 2900 N when a ball is kicked at a speed of 16.3 m/sec. Tol<sup>68</sup> found that the ball predominantly impacts with the antero-medial part of the foot/ankle and determined an impact force of 1025 N at an average ball speed of 24.6 m/sec. In almost half of all impacts (39%), the plantar flexion angles exceeded the maximum static plantar flexion angles. This means that the anterior part of the capsule and the joint are subjected to maximum strain. Prematurely forced kicks can negatively affect tissue regeneration and lead to impaired healing of ligaments and receptors after injury. Repetitive stress and destruction of the capsule and receptors can lead to chronic impairments (increased muscle reaction time, deafferentation, reduced sensory) and, in the long term, to a "footballer's ankle" (impingement syndrome).<sup>68,84</sup>

Arundale<sup>65</sup> describes an interval kicking progression (IKP) that can be adapted for ankle sprain rehabilitation. We recommend an individualised kicking progression from passing to kicking from short to long distance, taking into account tissue load capacity and stage of tissue healing. The kicking progression should be extended with athletic training skills (highly dynamic

running and sprinting with multidirectional cutting skills) to restore football-specific endurance and best prepare the athlete for partial participation in team training (next level RTP).