Supplementary Appendix to

Early versus delayed lengthening exercises for acute hamstring injury in male athletes: a randomised controlled clinical trial

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| Subject ID | Age | Sports/level       | Outcome | Study period timeline                                                                 |
|-----------|-----|--------------------|---------|--------------------------------------------------------------------------------------|
| HAR 8     | 18  | Athletics / Professional | RTS     | Went back to home country before finalising rehabilitation.                         |
|           |     |                    |         | **Censored: 12 days from injury**                                                    |
| HAR 10    | 32  | Hockey / Professional | RTS     | Stopped attending rehabilitation and did not respond to attempts at contact.         |
|           |     |                    |         | **Censored: 12 days from injury**                                                    |
| HAR 14    | 30  | Football / Professional | RTS     | Unhappy with progression and did not want to continue study rehabilitation.         |
|           |     |                    |         | Withdrew from study                                                                  |
| HAR 20    | 26  | Field Hockey / Professional | RTS     | Stopped attending rehabilitation and did not respond to attempts at contact.      |
|           |     |                    |         | **Censored: 21 days from injury**                                                    |
| HAR 26    | 30  | Football / Professional | RTS     | Unhappy with progression and stopped rehabilitation. Withdraw from study           |
|           |     |                    |         | **Censored: 52 days from injury**                                                    |
| HAR 33    | 24  | Handball / Professional | RTS     | Stopped attending rehabilitation and did not respond to attempts at contact.      |
|           |     |                    |         | **Censored: 8 days from injury**                                                     |
| HAR 34    | 24  | Handball / Professional | RTS     | Stopped attending rehabilitation and did not respond to attempts at contact.      |
|           |     |                    |         | **Censored: 22 days from injury**                                                    |
| HAR 46    | 19  | Football / Professional | RTS     | Stopped attending rehabilitation after exacerbation in sports-specific training.  |
|           |     |                    |         | Did not respond to attempts at contact.                                             |
| HAR 57    | 32  | Football / Professional | RTS     | Decided to retire from football.                                                   |
|           |     |                    |         | **Censored: 16 days from injury**                                                    |
| HAR 63    | 27  | Football / Competitive | RTS     | Stopped attending rehabilitation and did not respond to attempts at contact.      |
|           |     |                    |         | **Censored: 8 days from injury**                                                    |
| HAR 67    | 36  | Football / Professional | RTS     | Stopped attending rehabilitation and did not respond to attempts at contact.      |
|           |     |                    |         | **Censored: 5 days from injury**                                                    |
| HAR 72    | 30  | Football / Competitive | RTS     | Left the country during rehab.                                                     |
|           |     |                    |         | **Censored: 18 days from injury**                                                    |
| HAR 75    | 27  | Football / Professional | RTS     | Stopped attending before start of sports-specific training and did not respond to |
|           |     |                    |         | attempts at contact.                                                               |
|           |     |                    |         | **Censored: 54 days from injury**                                                    |
| Subject ID | Age | Sports/level | Outcome | Study period timeline |
|------------|-----|--------------|---------|-----------------------|
| HAR 2      | 34  | Basketball / Professional | RTS     | Played a game before finalising sports-specific training. DNA for return to sports assessments. **Self-decided return to sport: 18 days from injury** |
| HAR 7      | 24  | Football / Professional    | RTS     | Full team training after first sports specific session. DNA for return to sports assessments. **Self-decided return to sport: 16 days from injury** |
| HAR 18     | 32  | Football / Professional    | RTS     | Full team training after first sports specific session. DNA for return to sports assessment with SMP **Self-decided return to sport: 21 days from injury** |
| HAR 23     | 33  | Basketball / Professional | RTS     | Played games before completing rehabilitation. **Self-decided return to sport: 17 days from injury** |
| HAR 27     | 27  | Football / Professional    | RTS     | Full team training before sports-specific training. **Self-decided return to sport: 29 days after injury** |
| HAR 35     | 22  | Football / Professional    | RTS     | Full team training after 1 sports-specific session before completing rehabilitation. **Self-decided return to sport: 13 days from injury** |
| HAR 38 | 21 | Football / Professional | RTS | Played a full game before sports-specific sessions, club discouraged further attendance.  
**Self-decided return to sport: 20 days from injury** |
| HAR 45 | 19 | Football / Professional | RTS | Delayed sports-medicine physician return to sport assessment.  
**Date of last sports-specific session leading: 35 days from injury** |
| HAR 49 | 25 | Futsal / Professional | RTS | Played a full match before sports medicine physician return to sport assessment and no show for assessments.  
**Self-decided return to sport: 7 days from injury** |
| HAR 51 | 27 | Football / Competitive | RTS | Stopped attending rehabilitation and started full team training.  
**Self-decided return to sport: 43 days from injury** |
| HAR 52 | 26 | Football / Professional | RTS | Played half a game before discharge.  
**Self-decided return to sport: 8 days from injury** |
| HAR 58 | 27 | Rugby / Professional | RTS | Delayed sports-medicine physician return to sport assessment  
**Date of last sports-specific session leading: 35 days from injury** |
| HR 61 | 25 | Handball / Professional | RTS | Played a match before sports medicine physician return to sport assessment and no show for assessment.  
**Self-decided return to sport: 60 days from injury** |
| HAR 62 | 31 | Football / Professional | RTS | Delayed sports medicine physician return to sport assessment  
**Date of last sports-specific session leading: 16 days from injury** |
| HAR 66 | 33 | Handball / Professional | RTS | Finished sports-specific training but no show for return to sports assessments.  
**Date of last sports-specific session leading: 23 days from injury** |
| HAR 68 | 27 | Football / Professional | RTS | Played match before completing sports-specific training  
**Self-decided return to sport: 35 days from injury** |
| HAR 71 | 20 | Athletics / Professional | RTS | Played match before end of rehab and no show for return to sport assessments |
Table S3: Characteristics of participants with missing secondary outcome measures (reinjury rates)

| Subject ID | Age | Sports/level       | Outcome                        | Study period timeline                                      | Also censored for primary outcome measure? |
|------------|-----|--------------------|--------------------------------|------------------------------------------------------------|-------------------------------------------|
| HAR 2      | 34  | Basketball / Professional | Re-injury at 12 months         | Left the country after RTS and could not establish contact. | No                                        |
| HAR 8      | 18  | Athletics / Professional | Re-injury at 2, 6, 12 months   | Left the country before RTS and could not establish contact. | Yes                                       |
| HAR | Age | Sport | Injury | Reason | Contact Status |
|-----|-----|-------|--------|--------|----------------|
| 10  | 32  | Hockey | Re-injury at 2, 6, 12 months | Contact number not in use anymore. | Yes |
| 14  | 30  | Football | Re-injury at 2, 6, 12 months | Withdrew from study during rehabilitation phase. | Yes |
| 20  | 26  | Field Hockey | Re-injury at 2, 6, 12 months | No contact established after repeated attempts. | Yes |
| 26  | 30  | Football | Re-injury at 2, 6, 12 months | Withdrew from study during rehabilitation phase. | Yes |
| 33  | 24  | Handball | Re-injury at 2, 6, 12 months | No contact established after repeated attempts. | Yes |
| 34  | 24  | Handball | Re-injury at 2, 6, 12 months | No contact established after repeated attempts. | Yes |
| 38  | 21  | Football | Re-injury at 2, 6, 12 months | No contact established after repeated attempts. | No |
| 42  | 31  | Football | Re-injury at 6, 12 months | Left the country after RTS and could not establish contact. | No |
| 46  | 19  | Football | Re-injury at 2, 6, 12 months | No contact established after repeated attempts. | Yes |
| 49  | 25  | Futsal | Re-injury at 6, 12 months | Left the country after RTS and could not establish contact. | No |
| 52  | 26  | Football | Re-injury at 6, 12 months | No contact established for last two time point after repeated attempts. | No |
| 54  | 18  | Football | Re-injury at 12 months | No contact established for last time point after repeated attempts. | No |
| 56  | 22  | Handball | Re-injury at 12 months | No contact established for last time point after repeated attempts. | No |
| 58  | 27  | Rugby | Re-injury at 6, 12 months | Contact number not in use anymore. | No |
| 60  | 26  | Basketball | Re-injury at 6 months | Contact number not in use anymore. Contact at 12 months established through his previous club physiotherapist. | No |
| HAR   | Age | Sport          | Time of Re-injury | Outcome of Contact Attempts | Re-injury After Attempts |
|-------|-----|----------------|------------------|----------------------------|-------------------------|
| HAR 61| 25  | Handball / Professional | Re-injury at 12 months | No contact established for first two time points after repeated attempts. | No                      |
| HAR 62| 31  | Football / Professional | Re-injury at 6 months | No contact established for second time point after repeated attempts. | No                      |
| HAR 63| 27  | Football / Competitive  | Re-injury at 2, 6, 12 months | No contact established after repeated attempts. | Yes                    |
| HAR 66| 33  | Handball / Professional | Re-injury at 2, 6, 12 months | No contact established after repeated attempts. | No                      |
| HAR 67| 36  | Football / Professional | Re-injury at 2, 6, 12 months | No contact established after repeated attempts. | Yes                    |
| HAR 69| 27  | Football / Professional | Re-injury at 6, 12 months | Left the country and could not establish contact. | No                      |
| HAR 75| 27  | Football / Professional | Re-injury at 2, 6, 12 months | No contact established after repeated attempts. | Yes                    |
| HAR 79| 19  | Football / Professional | Re-injury at 2, 6, 12 months | No contact established after repeated attempts. | Yes                    |
| HAR 81| 24  | Futsal / Professional  | Re-injury at 2, 6, 12 months | No contact established after repeated attempts. | Yes                    |
| HAR 83| 29  | Football / Professional | Re-injury at 2, 6, 12 months | No contact established after repeated attempts. | Yes                    |
| HAR 87| 34  | Football / Professional | Re-injury at 2, 6 months | No contact established for first two time points after repeated attempts. | Yes                    |

*HAR: Hamstring rehabilitation study, RTS: return to sport*
Table S4 Other outcome measures

|                                | Early Lengthening | Delayed Lengthening |
|--------------------------------|-------------------|---------------------|
|                                | n | Mean ± SD | 95% CI | n | Mean ± SD | 95% CI |
| Askling H-test (insecurity yes/no) | 2/25 |             |         | 3/29 |             |         |
| Nordic Hamstring Test Peak force per leg (in Newton) |   |            |         |     |            |         |
| Uninjured                        | 11 | 303.6±106.0 | 232–374 | 23 | 328.1±101.3 | 284–372 |
| Injured                          | 11 | 287.2±100.4 | 220–355 | 23 | 315.7±75.0  | 283–348 |
| Imbalance injured vs uninjured (%) | 11 | -4.4±12.9  | -13.1–4.3 | 23 | -1.3±14.4  | -7.5–4.9 |
| Nordic Hamstring Test Average force per leg (in Newton) |   |            |         |     |            |         |
| Uninjured                        | 11 | 275.3±105.7 | 204–346 | 23 | 301.9±96.2  | 260–344 |
| Injured                          | 11 | 265.9±101.0 | 198–334 | 23 | 294.1±72.6  | 263–326 |
| Imbalance injured vs uninjured (%) | 11 | -1.6±14.5  | -11.3–8.2 | 23 | 0.06±15.1  | -6.5–6.6 |
| Isokinetic measurements per leg (in Nm): |   |            |         |     |            |         |
| Quadriceps concentric 60°/s      |   |            |         |     |            |         |
| Uninjured                        | 28 | 234.2±38.7 | 219–249 | 31 | 224.5±59.4  | 203–246 |
| Injured                          | 28 | 239.9±37.0 | 226–254 | 31 | 219.7±49.5  | 202–238 |
| Hamstring concentric 60°/s       |   |            |         |     |            |         |
| Uninjured                        | 28 | 133.0±30.3 | 121–145 | 31 | 123.7±32.7  | 112–136 |
| Injured                          | 28 | 121.2±24.3 | 112–131 | 31 | 111.6±26.9  | 102–122 |
| Quadriceps concentric 300°/s     |   |            |         |     |            |         |
| Uninjured                        | 28 | 148.0±20.4 | 140–156 | 31 | 136.4±30.0  | 125–147 |
| Injured                          | 28 | 146.9±25.5 | 137–157 | 31 | 134.4±28.3  | 124–145 |
| Hamstring concentric 300°/s      |   |            |         |     |            |         |
| Uninjured                        | 28 | 102.3±17.5 | 95–109  | 31 | 97.5±26.9   | 88–107  |
| Injured                          | 28 | 97.5±18.0  | 91–104  | 31 | 90.2±22.0   | 82–98   |
| Hamstring eccentric 60°/s        |   |            |         |     |            |         |
| Uninjured                        | 28 | 206.9±33.4 | 194–220 | 31 | 200.6±52.6  | 181–220 |
| Injured*                         | 28 | 205.7±45.5 | 188–223 | 31 | 184.0±46.5  | 167–201 |
| Length of palpation pain (in cm) | 27 | 0.1±0.6    | 0–0      | 33 | 0.5±2.1     | 0–1     |
| Width of palpation pain (in cm)  | 28 | 0.0±0.2    | 0–0      | 33 | 0.3±1.3     | 0–1     |
| Distance from tuber to maximal palpation pain | 27 | 1.1±5.6 | -1–3 | 32 | 0.5±2.7 | 0–1 |
| MHFAKE relative deficit (in % of uninjured leg) | 26 | 99.3±6.1 | 97–102 | 33 | 99.3±9.8 | 96–103 |
| SLR relative deficit (in % of uninjured leg) | 27 | 100.4±5.1 | 98–102 | 33 | 100.5±4.4 | 99–102 |
| PKET relative deficit (in % of uninjured leg) | 23 | 99.0±5.5 | 97–101 | 24 | 101.7±4.2 | 100–103 |
| Pain (and ability to perform) clinical strength tests† (no pain/pain) |   |            |         |     |            |         |
| Inner                           | 26/0 |             |         | 33/0 |             |         |
| Mid                             | 26/1 |             |         | 32/1 |             |         |
| Outer                           | 26/1 |             |         | 33/0 |             |         |
| Relative force deficit for clinical strength tests† (in % of uninjured leg) |   |            |         |     |            |         |
| Group       | N | Rate of Recovery (%) | Confidence Interval (%) |
|------------|---|---------------------|-------------------------|
| Inner      | 26| 92.4±13.2           | 87–98                   |
| Mid        | 27| 96.3±19.2           | 89–104                  |
| Outer      | 26| 98.9±13.2           | 94–104                  |

**Participant readiness questions (rate of recovery 5-point Likert and continuous in %)**

| Category              | N | Continuous Scale (%) |
|-----------------------|---|----------------------|
| Recovered a lot       | 8 | 94.0±8.6             |
| Completely recovered  | 19| 91–97                |

**Participant readiness questions (fear of sustaining reinjury 5-point Likert and continuous in %)**

| Category              | N | Continuous Scale (%) |
|-----------------------|---|----------------------|
| Definitely reinjure   | 0 | 18.3±22.5            |
| Probably reinjure     | 2 | 9–27                 |
| Maybe reinjure        | 4 | 21.3±29.2            |
| Definitely not reinjure| 13| 11–32                |

*Statistically significant difference between the groups (p = 0.029). PKET; Passive Knee Extension Test, SLR; Straight Leg Raise test, MHFAKE; Maximum Hip Flexion Active Knee Extension test. Inner; prone knee flexion 90°, Mid; prone knee flexion 30°, Outer; supine knee/hip flexion 90°/90°. †for cases that do not add up to 44, data was missing.

**Table S5 Research management**

| Name | Role                        | Timeline                |
|------|-----------------------------|-------------------------|
| AW   | Coordinating researcher, principal investigator | 2013 - 10/2015, 2013 - 08/2016 |
| AvdM | Coordinating researcher     | 10/2015 - 10/2016       |
| RV   | Coordinating researcher     | 10/2016 - 2020          |
| RW   | Principal investigator      | 08/2016 - 2020          |
Figure S1: Participant flow and blinding diagram
Description of rehabilitation protocol stages and progression criteria:

*Physiotherapy stage one:* The main aim in stage one was to promote healing and avoid provocative activities that might delay return to sport. We used low load exercises during the early phase of healing, typically active movements in mid and inner range of knee- and hip flexion, soft tissue mobilisation and isometric or easy concentric exercises.

*Criteria to progress to physiotherapy stage two:* We allowed a participant to progress to physiotherapy stage two if they could perform a single leg squat pain free and stationary cycle for five minutes. They had to maintain a power output of 150% (in W) of their bodyweight (in kg) during this cycling.

*Physiotherapy stage two:* The load of the exercises in stage one were progressed. We also introduced the running progression programme in this stage.

*Running progression:* The running progression programme addressed volume and intensity (and mechanics, to an extent). A proper warm-up was ensured through stationary cycling or slow running before the participant started the running drills. Participants performed technique drills called the “triple extension jumps” and “B” drill before every set of running. These drills emphasise the late swing and triple extension phases of running. The running was performed on an oval track with approximately 30 metre straights and an approximately 100 metre total circumference. The participants walked between the straights and accelerate into a straight to reach their designated speed before decelerating into the corners again. Per session they completed 3x1 set of drills and 3x4 sets of running. To ensure progression and similar loads across sessions we asked participants to rate their perceived effort on a visual analogue scale of 0 to 100%, with a 100% being a maximum effort sprint and 0% being their slowest possible running speed. With this scale, we asked participants to rate their current speed compared to their maximum speed during each set. Furthermore, we timed their 30 metre times with a handheld stopwatch as an objective comparison. Running speed was progressed by 5-10% during each session if the participant completed a set without pain and reported confidence in progressing the loading. If they experienced discomfort, lacked adequate control (e.g. limping or favouring a leg) or were not confident we instructed them to return to the percentage of speed of their previous set.

*Criteria to progress to physiotherapy stage three:* The participants could progress to physiotherapy stage three if they were able to run pain-free at more than 70% of self-rated maximal speed.

*Physiotherapy stage three:* The exercises from previous stages were progressed in load. Eccentric biased exercises (specifically the Nordic hamstring exercise) were introduced and progressed in this stage. In the running progression, change of direction using a modified T-drill was added as an addition to the linear running protocol. Progression of this modified T-drill was done in the same way as the linear running but started at 60% self-rated maximum speed.
Criteria to progress to sports-specific training stages 4-6: Progression to on-field sports-specific training was allowed if the participant could run at 100% self-rated speed in both the linear running and the modified T-drill.

Sports-specific training stages 4-6: We required the participant to complete three 30 – 45 minute sessions of sports-specific training with a sports rehabilitator (blinded to the intervention). This was typically done over three to four days. The overall goals of these stages were to mimic training and game situations and they emphasised running, sprinting, change of direction and sports-specific skills. For example, in football, these sport specific skills included passing/kicking/shooting scenarios, scoring scenarios and competitive one versus one drills. We returned participants to a previous stage in rehabilitation if they were not able to perform these skills or reported pain with these activities.
**DAILY PHYSICAL EXAMINATION AND TREATMENT FORMS**

**HAMSTRING REHABILITATION STUDY**

### Daily assessments

| Injured leg: | LEFT | RIGHT |
|--------------|------|-------|
| No = no pain, P = pain, NA = not able, SLR = straight leg raise. MHFAKE = maximal hip flexion active knee extension. * = degrees, kg = kilograms |

|                         | / 201_ Days Post: | / 201_ Days Post: | / 201_ Days Post: | / 201_ Days Post: | / 201_ Days Post: |
|-------------------------|------------------|------------------|------------------|------------------|------------------|
| **Average pain today**  | VAS /10          | VAS /10          | VAS /10          | VAS /10          | VAS /10          |
| **Walking**             | No P NA          | No P NA          | No P NA          | No P NA          | No P NA          |
| **Jogging**             | No P NA          | No P NA          | No P NA          | No P NA          | No P NA          |
| **2 leg squat x 3**     | No P NA          | No P NA          | No P NA          | No P NA          | No P NA          |
| **1 leg squat x 3**     | No P NA          | No P NA          | No P NA          | No P NA          | No P NA          |
| **Trunk flexion**       | No P NA          | No P NA          | No P NA          | No P NA          | No P NA          |
| **Total palp. length:** | cm P             | cm P             | cm P             | cm P             | cm P             |
| **Mid range**           | kg P | kg P | kg P | kg P | kg P |
| **Outer range**         | kg P | kg P | kg P | kg P | kg P |
| **SLR**                 | * P | * P | * P | * P | * P |
| **MHFAKE**              | * P | * P | * P | * P | * P |
| **Bent leg bridge 3x**  | No P NA          | No P NA          | No P NA          | No P NA          | No P NA          |
| **Straight leg bridge 3x** | No P NA          | No P NA          | No P NA          | No P NA          | No P NA          |

**Comments:**

|                         | / 201_ Days Post: | / 201_ Days Post: | / 201_ Days Post: | / 201_ Days Post: | / 201_ Days Post: |
|-------------------------|------------------|------------------|------------------|------------------|------------------|
| **Average pain today**  | VAS /10          | VAS /10          | VAS /10          | VAS /10          | VAS /10          |
| **Walking**             | No P NA          | No P NA          | No P NA          | No P NA          | No P NA          |
| **Jogging**             | No P NA          | No P NA          | No P NA          | No P NA          | No P NA          |
| **2 leg squat x 3**     | No P NA          | No P NA          | No P NA          | No P NA          | No P NA          |
| **1 leg squat x 3**     | No P NA          | No P NA          | No P NA          | No P NA          | No P NA          |
| **Trunk flexion**       | No P NA          | No P NA          | No P NA          | No P NA          | No P NA          |
| **Total palp. length:** | cm P             | cm P             | cm P             | cm P             | cm P             |
| **Mid range**           | kg P | kg P | kg P | kg P | kg P |
| **Outer range**         | kg P | kg P | kg P | kg P | kg P |
| **SLR**                 | * P | * P | * P | * P | * P |
| **MHFAKE**              | * P | * P | * P | * P | * P |
| **Bent leg bridge 3x**  | No P NA          | No P NA          | No P NA          | No P NA          | No P NA          |
| **Straight leg bridge 3x** | No P NA          | No P NA          | No P NA          | No P NA          | No P NA          |

**Comments:**

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Vermeulen R, et al. *Br J Sports Med* 2022; 56:792–800. doi: 10.1136/bjsports-2020-103405
### HAMSTRING REHABILITATION STUDY

**PROTOCOL - Aspetar**

**Weight:**

- Leg injured: [ ] LEFT  [ ] RIGHT

| WEEK | STAGE | TREATMENT | SETS/REPS | SIGN: / / 201_ | SIGN: / / 201_ | SIGN: / / 201_ | SIGN: / / 201_ | SIGN: / / 201_ | SIGN: / / 201_ | SIGN: / / 201_ |
|------|-------|-----------|-----------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| 1    | 1     | LEG SQUAT | 3 x 15    |                |                |                |                |                |                |                |
|      | 1     |           | 3 x 15    |                |                |                |                |                |                |                |
| 1    | 1     | EXERCISE BIKE | 5 mins |                |                |                |                |                |                |                |
| 1    | 2     | SUPINE BRIDGE 2 LEGS | 3 x 12 |                |                |                |                |                |                |                |
| 1    | 2     | SUPINE ISOMETRIC HEEL DIPS | 3 x 12 |                |                |                |                |                |                |                |
| 1    | 2     | SINGLE LEG SQUAT → 45° | 3 x 8 |                |                |                |                |                |                |                |
| 1    | 2     | MANUAL RESISTED HAMSTRINGS | 3 x 12 |                |                |                |                |                |                |                |
| 1    | 2     | SOFT TISSUE | 5 mins |                |                |                |                |                |                |                |
| 2    | 2     | SUPINE BRIDGE 1 LEG | 4 x 15 |                |                |                |                |                |                |                |
|      | 3     | STRETCHING (SLR and PRI) | 3 x 30 s |                |                |                |                |                |                |                |
| 3    | 1     | "THE EXTENDER" | 3 x 12 |                |                |                |                |                |                |                |
|      | 1     | Daily | 3 x 6 |                |                |                |                |                |                |                |
| 3    | 2     | "ARABESQUE/DIVER" | 4 x 15 |                |                |                |                |                |                |                |
|      | 2     | Every 2nd day | 4 x 8 |                |                |                |                |                |                |                |
| 3    | 2     | "THE GLIDER" | 3 x 6 |                |                |                |                |                |                |                |
|      | 2     | Every 3rd day | 3 x 6 |                |                |                |                |                |                |                |
| 3    | 3     | RESISTED HAMSTRINGS | 4 x 15 |                |                |                |                |                |                |                |
|      | 3     | 1. Prone leg curl | 4 x 8 |                |                |                |                |                |                |                |
|      | 3     | 2. Prone leg curl eccentric | 4 x 15 |                |                |                |                |                |                |                |
|      | 3     | Nordic hamstring | 2 x 5 |                |                |                |                |                |                |                |

**Criteria for progression from Stage 1 to Stage 2:**
1. Painless Single Leg Squat
2. Painless Bike, W: 2x Body Weight, 5 minutes (level 6-7)

**Criteria for progression from Stage 2 to Stage 3:**
1. Run ≥ 70% Patient-rated

**Criteria for progression from Stage 3 to Sports Spec Rehab:**
1. 100% running speed
2. Painless high speed direction changes

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### HAMSTRING REHABILITATION STUDY

**PROTOCOL -Aspetar + Early Lengthening Exercises**

#### Weight:
- Leg injured: LEFT RIGHT

#### Criteria for progression from Stage 1 to Stage 2:
1. Painless Single Leg Squat
2. Painless Bike, W: 2x Body Weight, 5 minutes (level 6-7)

#### Criteria for progression from Stage 2 to Stage 3:
1. Run ≥ 70% Patient-rated

#### Criteria for progression from Stage 3 to Sports Spec Rehab:
1. 100% running speed
2. Painless high speed direction changes

| WEEK | STAGE | TREATMENT | SETS/REPS | Sign: / / | /101 | Sign: / / | /101 | Sign: / / | /101 | Sign: / / | /101 | Sign: / / | /101 |
|------|-------|-----------|-----------|-----------|-------|-----------|-------|-----------|-------|-----------|-------|-----------|-------|
|      | 1     | 2 LEG SQUAT Prop: with weights | 3 x 15 | 3 x 8 | | | | | | | | | |
|      | 1     | EXERCISE BIKE (Watt: 2x BW) 5 min + 5 min | 5 mins | | | | | | | | | | |
|      | 1     | SUPINE BRIDGE 2 LEGS | 3 x 12 | | | | | | | | | | |
|      | 1     | SUPINE ISOMETRICHEEL DIPS | 3 x 12 | | | | | | | | | | |
|      | 1     | SINGLE LEG SQUAT → 45° Prop: with weights | 3 x 8 | 3 x 15 | | | | | | | | | |
|      | 1     | MANUAL RESISTED HAMSTRINGS | 3 x 12 | | | | | | | | | | |
|      | 1     | SOFT TISSUE | 5 mins | | | | | | | | | | |
|      | 1     | ACTIVE ROM | 3 x 8 | | | | | | | | | | |
|      | 1 2 3 | THE EXTENDER Daily | (3 x 12) x 2 | | | | | | | | | | |
|      | 1 2 3 | ARABESQUE/DIVER Every 2nd day | 3 x 6 | | | | | | | | | | |
|      | 1 2 3 | THE GLIDER Every 3rd day | 3 x 6 | | | | | | | | | | |
|      | 2 3 | SUPINE BRIDGE 1 LEG 2 sec up/2 sec down | 4 x 15 | | | | | | | | | | |
|      | 2 3 | STRETCHING (SLR and PKET) | 3 x 30 s | | | | | | | | | | |
|      | 2 3 | RESISTED HAMSTRINGS 1. Prone leg curl | 4 x 15 | | | | | | | | | | |
|      | 2 3 | 2. Prone leg curl eccentric | 4 x 8 | | | | | | | | | | |
|      | 3     | ECCENTRIC STRENGTHENING Nordic hamstring | 2 x 5/3 x 6 | | | | | | | | | | |
# HAMSTRING REHABILITATION STUDY

## Running and sprinting protocol

**Leg injured:** □ LEFT □ RIGHT

| WEEK | PREPARATION EXERCISES | Sets/ laps | Sign: | / 201 | Sign: | / 201 | Sign: | / 201 | Sign: | / 201 | Sign: | / 201 | Sign: | / 201 | Sign: | / 201 | Sign: | / 201 |
|------|-----------------------|------------|-------|--------|-------|--------|-------|--------|-------|--------|-------|--------|-------|--------|-------|--------|-------|--------|
| 2 x 3 | Triple Extension Walk High knee only | 3 x 1 | | | | | | | | | | | | | | | | |
| | "11" Drill High knee with "Kicks" | | | | | | | | | | | | | | | | |
| 2 x 3 | RUNNING REGRESSION | Sets/ laps | Best Time | % max | Sets/ laps | Best Time | % max | Sets/ laps | Best Time | % max | Sets/ laps | Best Time | % max | Sets/ laps | Best Time | % max | Sets/ laps | Best Time | % max |
| 3 | Comments: | Set I: | Set I: | Set I: | Set I: | Set I: | Set I: | Set I: | Set I: | Set I: | | | | | | | | |
| | | Set II: | Set III: | Set III: | Set III: | Set III: | Set III: | Set III: | Set III: | Set III: | | | | | | | | |
| 3 | Modified T-Drill [70 – 100%] [≤ 3 sec.] | 3 x 1 | | | | | | | | | | | | | | | | |
| | Comments | Set I: | Set I: | Set I: | Set I: | Set I: | Set I: | Set I: | Set I: | Set I: | | | | | | | | |
| | | Set II: | Set II: | Set II: | Set II: | Set II: | Set II: | Set II: | Set II: | Set II: | | | | | | | | |
| | | Set III: | Set III: | Set III: | Set III: | Set III: | Set III: | Set III: | Set III: | Set III: | | | | | | | | |
| PROGRESSION | Walk – Jog: begin running at 10-25% (patient-rated), progression by 10% step to max 70%. | | | | | | | | | | | | | | | | |
| | Jog – Run and Modified T-Drills: begin running at 70% (patient-rated), progress as able by 10%. At 90%, progress by 5%. | | | | | | | | | | | | | | | | |

**Patient label**
### Exercises and exercise progression

*(see also the video supplement at [https://www.youtube.com/watch?v=Fzex_zG1JtA](https://www.youtube.com/watch?v=Fzex_zG1JtA))*

| Stage | Name of Exercise | Sets/Reps | Starting position | Instruction/movement | Progression of the exercise |
|-------|------------------|-----------|-------------------|----------------------|----------------------------|
| 1     | 2 LEG SQUAT → 90°| 3 x 15↓ 3 x 8 | The athlete is standing with: → the feet one 1/2 hip-width apart → thighs towards end of the bench with a height similar to the knee joint line → hands on the hip → pelvis horizontal; knees above the toes, pointing in a straight line forward | The athlete is asked to lower his body by bending his knees until he touches the bench while the knees are directly in a line above the feet (2nd toe). The upper body is supposed to be as straight as possible. *Ensure: Knees over toes, heels on the ground.* | I: Deeper squats II: Manual weights added: one weight in each hand → repetitions reduced to 3 x 8 |
| 1     | EXERCISE BIKE (Watt: 2xBodyweight) | 5 min | In the first session after the injury, the athlete starts at 50 Watt for 30 sec. Thereby he increases the load/intensity with 25 W every 30 seconds until he reaches the highest level where he can cycle for 5 minutes continuously. | | |
| 1 2   | SUPINE BRIDGE 2 LEGS | 3 x 12 | Athlete is lying supine with arms placed in a comfortable position. Both feet are placed flat and both knees in a flexed position. The knee flexion angle is obtained by flexing one leg first from an extended position, so the posterior calcaneus is placed next to the medial knee joint line of the contralateral leg, which is then placed in a similar fashion. | The athlete is instructed to push down through the heels to lift the bottom off the ground until the hip is extended to 0°. *Ensure: Good quality, i.e.: ASIS/pelvis horizontally throughout the whole movement* | I: Cross arms II: Supine Bridge 1 Leg |
| 1 2   | SUPINE ISOMETRIC HEEL DIGS | 3 x 12 | Athlete is lying supine or sitting on the bench with the knees flexed at an angle of approximately 90°. | The athlete is instructed to push down through the heel by activating the hamstrings and hold the position for approximately 5 secs. | Isometric contractions in different knee angles towards end ROM; 90° - 60° - 30° |
| 1 2   | SINGLE LEG SQUAT → 45° | 3 x 8 | The athlete is standing: → on the injured leg with the contralateral leg slightly bent → one feet distance from the end of a bench (mid-thigh level) → hands on the hip | The athlete is asked to lower the body in a squatting position by bending his knees until he touches the examination table while the knee on the standing leg is directly in a line above the feet (2nd toe). *Ensure: Correct alignment and adequate control/stability of the trunk, hip and knees, i.e. minimal lateral pelvic tilt, minimal knee valgus.* | I: Manual weights are added: the athlete holds one weight in each hand and performs the same movement. The number of repetitions is reduced to 3 x 8. |
**MANUAL RESISTED HAMSTRINGS**

| Reps | Description |
|------|-------------|
| 3 x 12 | Athlete is lying in prone position with knees flexed. The therapist applies isometric resistance in varying angles. Athlete is instructed to push against the therapist’s hand, which is placed on the posterior calcaneus. |

**SOFT TISSUE**

| Duration | Description |
|----------|-------------|
| 5 min | Athlete is lying in prone position. Effleurages/lymphatic drainage is performed distal and proximal to injury site. Athlete is instructed to be relaxed and report if he feels pain or any kind of discomfort during the treatment. |

**ACTIVE ROM**

| Reps | Description |
|------|-------------|
| 3 x 8 | Athlete is lying in prone position with both legs extended. Athlete is instructed to actively flex the knee of the injured leg until the heel touches the buttock and then slowly extend the knee towards a straight leg position again. |

**“THE EXTENDER”**

| Reps | Description |
|------|-------------|
| 3 x 12 | The athlete is lying supine and holds/stabilizes the thigh of the injured leg with the hip flexed approximately 90°. The athlete is instructed to perform slow knee extensions to a point just before pain is felt. |

**“DIVER”**

| Reps | Description |
|------|-------------|
| 3 x 6 | The athlete is standing with full weight on his injured leg and the opposite knee slightly flexed. The hips are extended and the hands are touching in front of the breast. The athlete is asked to perform the exercise as a simulated dive (hip flexion from an upright trunk position) of the injured, standing leg and simultaneous stretching arms forward and attempting maximal hip extension of the lifted leg while keeping the pelvis horizontal; angles at the knee should be maintained at 10–20° in the standing leg and at 90° in the lifted leg. I Ensure: Correct alignment of the pelvis and no movement of the LB. |

**“THE GLIDER”**

| Reps | Description |
|------|-------------|
| 3 x 6 | The exercise is started with the athlete positioned with upright trunk, one hand holding on to a support and legs slightly split. All the body weight should be on the heel of the injured leg with approximately 10–20° flexion in the knee. The athlete is instructed to perform a gliding backward movement on the other leg and stop the movement before pain is reached. The movement back to the starting position should be performed by the help of both arms, not using the injured leg. Progression is achieved by increasing the gliding distance and performing the exercise faster. |

**SUPINE BRIDGE 1 LEG**

| Reps | Description |
|------|-------------|
| 4 x 15 | Athlete is lying supine with the arms placed in a comfortable position. The athlete is instructed to push down through the heel to lift the bottom off the ground until 1 sec up – 2 sec down (4 x 8). |

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**Supplemental material**

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|   |   |   |   |   |
|---|---|---|---|---|
|   |   | contralateral leg is required to be off the examination bench in an optional (flexed) position. | the hip is extended to 0°. Both ASIS are required to be horizontal throughout the whole movement to ensure a good quality. |
|   |   | Ensure: Good quality, i.e.: ASIS/pelvis horizontally throughout the whole movement | Ensure: Hips extended until 0°, i.e. straight line shoulder – hips – knees |
| 2 | 3 | **STRETCHING** (SLR and MHFPKET) | II: On exercise ball or BOSU (4 x 8) |
|   |   | 3 x 30 s |   |
|   |   | Athlete is lying prone. |   |
|   |   | The athlete is instructed to relax. The therapist performs a gentle stretch with the leg in a: |   |
|   |   | 1) Straight Leg Raise position |   |
|   |   | 2) Maximal hip flexion + knee extension position. |   |
|   |   | Towards the end ROM where the athlete either reports a stretch or onset of pain, 5 isometric contractions are performed (hold-release), before a gentle passive stretch is applied further. Repeated 3 times in both positions (approximately 30s each position) |   |
| 2 | 3 | **RESISTED HAMSTRINGS** Prone leg curl | I: Increasing load (kg)  
II: Increasing load in eccentric phase |
|   |   | 4 x 15  
↓  
4 x 8 |   |
|   |   | Athlete is lying prone in the leg curl machine. Make sure the length of the lever arms is adjusted to the athlete’s leg length. |   |
|   |   | The athlete is instructed to perform slow continuous knee flexions and knee extensions with the injured leg, only, starting with a load that is acceptable (i.e. pain free). If the athlete is not able to perform the leg curl with the injured leg only, he can assist with the uninjured leg. |   |
| 3 |   | **ECCENTRIC STRENGTHENING** Nordic hamstring exercise | * Complete 2 pain-free sessions before progression to next level  
* Complete all 3 sessions, drop only, then progress through sessions again with drop and curl 3 times per week  
1) 2x 5 reps, drop only  
2) 2(3)x 5 – 8, drop only  
3) 2(3)x 8 – 12, drop only  
4) Repeat sessions 1-3 with drop AND curl |
|   |   | 2 x 5/  
3 x 6 |   |
|   |   | The athlete is kneeling on either the Nordbord with ankles fixed or on a mat with the therapist fixating the ankles. |   |
|   |   | The athlete is then instructed to fall forwards and resist the fall against the ground as long as possible using their hamstring muscle. |   |
|   |   | * Ensure: That the loading of the injured leg is similar to the uninjured leg (without pain). Be aware that the athlete is not leaning more towards the uninjured side. |   |
Statistical Analysis Plan MAIN OUTCOMES HAR study

Version 1.0    -     4/03/2020

Authors: Robin Vermeulen, Johannes L. Tol, Rodney Whiteley, Roald Bahr, Anne van der Made, Nicol van Dyk, Abdulaziz Farooq, Arnlaug Wangensteen

Primary Outcome Measure: time to RTS, defined as “number of days between injury and return to full unrestricted training and/or match play”.

Secondary outcome Measures: re-injury ≤2, 2 – 6 and 6-12 months, defined as an acute hamstring strain injury at the same site occurring within 2, 2 – 6 and 6-12 months from RTS.

Intervention: blinded, randomised controlled clinical trial. Aspetar standardized physiotherapy protocol versus Aspetar+, standardized physiotherapy protocol including early lengthening exercises.

Table 1: Baseline variables (as per protocol)

| Description of baseline variable                                      | Unit and Type of data                                      |
|-----------------------------------------------------------------------|------------------------------------------------------------|
| Patient history:                                                      |                                                            |
| ▪ Age                                                                 | Years (continuous)                                         |
| ▪ Previous hamstring injury                                           | Yes/no (dichotomous)                                      |
| ▪ Previous ipsilateral hamstring injury                               | Yes/no (dichotomous)                                      |
| ▪ Previous ipsilateral hamstring autograft for ACLR                   | Yes/no (dichotomous)                                      |
| ▪ Time of injury                                                      | During training/match (dichotomous)                       |
| ▪ Time of injury during training or match                             | Quarter injured; 1st, 2nd, 3rd or 4th (categorical)       |
| ▪ Type of injury                                                      | Sprinting, kicking, tackling, stretching (categorical)     |
| ▪ Dominant leg injured                                                | Yes/no (dichotomous)                                      |
| ▪ Training volume                                                     | Hours per week (continuous)                               |
| ▪ Days before start of rehabilitation after initial injury            | Number of days (continuous)                               |
| ▪ Patient expectation for performance after recovery                  | In % (continuous)                                         |
| ▪ Prediction of patient for time to RTS                               | Number of days (continuous)                               |
| ▪ Maximal pain score during injury                                    | Visual analogue scale (VAS) 0-10                           |
| Clinical assessments:                                                 |                                                            |
| ▪ Length and width of pain palpation                                  | cm (continuous)                                           |
| ▪ Distance from lower margin of the tuber to maximal pain palpation   | cm (continuous)                                           |
| ▪ Maximum Hip Flexion Active knee extension deficit                   | Relative to uninjured in %                                 |
| ▪ Passive straight leg raise deficit                                  | Relative to uninjured in %                                 |
| ▪ Passive knee extension deficit                                      | Relative to uninjured in %                                 |
| ▪ Pain (and ability to perform) individual clinical strength tests*   | Yes/no (dichotomous)                                      |
| ▪ Peak force deficit for individual clinical strength tests*          | Relative to uninjured in %                                 |
| MRI assessments:                                                      |                                                            |
| ▪ Longitudinal length of oedema                                       | mm (continuous)                                           |
| ▪ Cross-sectional area of oedema (in mm²)                             | mm² (continuous)                                          |
| ▪ Grade of injury (according to modified Peetrons)                    | Grade 0-3 (ordinal)                                       |
| ▪ Distance from tuber to start of oedema & to maximum amount of oedema| mm (continuous)                                           |
Supplemental material

Involvement of central tendon
- Affected CSA% 0% (not involved), <50%, 50-99%, 100% (Ordinal)

Compliance
- Number of rehabilitation sessions performed
  - % of maximum possible attendance (ie. (days attended/maximum possible attendance (excluding weekends))*100%

ACLR – anterior cruciate ligament reconstruction;
*Performed with 3 different ranges; “inner range”/”mid range”/”outer range”

Baseline variables will be assessed for normality through visual assessment of histograms and Q-Q plots. Descriptive data will be reported with mean values (±SD) or median values (IQR) for continuous variables, and as proportions (in %) for categorical data. Baseline variables differences between the groups will be assessed with an independent t-test or the non-parametric equivalent (Mann-Whitney U test) for continuous variables and with a Chi-Square test for categorical variables.

Statistical principles

After the 52 weeks follow-up of the last patient in the study, a standard operating procedure will be available to logically recode and clean the data. A biostatistician with extensive statistical expertise in sports medicine research (AF) is present among the authors and will conduct the blinded analysis. The authors will interpret the (still blinded) statistical results until a consensus is reached. The coordinating researcher (RV) was not blinded and will not take part in this interpretation and consensus. Once the other authors are in agreement, the two groups will be unblinded and no changes will be made to the interpretation of the results. The principal investigator and other project members will be unblinded only after the analysis of the primary outcome.

Primary outcome analysis:

Analysis of primary outcome measure, time to RTS (in days), will consist of a Cox proportional hazards model for survival time (Cox regression analysis). Censoring will occur at the time of last follow-up for the participants that have been lost-to-follow up. A sensitivity analysis will be performed to ensure robustness of results. In the sensitivity analysis the censored cases were considered not to have reached RTS until the 12 months (365 days) follow-up. The primary outcome (time to RTS) will be adjusted for baseline variables that are significantly different between the groups (p<0.05) and that change ≥10% of the treatment effect (hazard ratio). Time-to-event curves will be calculated with the Kaplan-Meier method and presented as cumulative survival plot.

Treatment effect analysis (intention to treat)

Test: Cox proportional hazards model

Time variable: Time to RTS/censored (in days)

Status variable: 0 = Censored, 1 = RTS reached

Data will be reported in Hazard Ratios (HR) plus 95% confidence intervals. If adjustment for baseline variables has taken place, an adjusted hazard ratio plus 95% confidence intervals will also be reported.
Secondary outcome analysis:

Analysis of secondary outcome measures, the difference in re-injury rates within 2 months, 6 & 12 months between the 2 treatment groups, will consist of a binary logistic regression analysis. Data will be reported in Odds-ratios (OR) plus 95% confidence intervals.

Other outcome measures

Table 2: Other outcome measures and analysis (as per protocol):

| Description of other outcome variables | Unit and Type of data |
|----------------------------------------|-----------------------|
| Clinical assessments at return to sport |                       |
| ▪ Askling H-test                        | Insecurity during the test yes/no (dichotomous) |
| ▪ Nordic Hamstring Test Peak force per leg | Newton (N) (continuous) |
|    MDC up to 76.2 N                    |                       |
| ▪ Nordic Hamstring Test Peak force imbalance between legs | In % (continuous) |
|    MDC up to 17%                      |                       |
| ▪ Nordic Hamstring Test Average force per leg | Newton (N) (continuous) |
|    MDC up to 68.5 N                   |                       |
| ▪ Nordic Hamstring Test Average force imbalance between legs | In % (continuous) |
|    MDC up to 11%                      |                       |
| ▪ Isokinetic measurements per leg:     | Newton-meter (Nm) (continuous) |
|    - Quadriceps concentric 60°/s      | Force deficit relative to uninjured leg in % (continuous) |
|    - Hamstring concentric 60°/s       |                       |
|    - Quadriceps concentric 300°/s     |                       |
|    - Hamstring concentric 300°/s      |                       |
|    - Hamstring eccentric 60°/s        |                       |
|    MDC: quadriceps up to 20.6%, hamstrings up to 24% |                       |
| ▪ Length and width of palpation pain  | Cm (continuous) |
| ▪ Distance from tuber to maximal palpation pain | Cm (continuous) |
| ▪ Maximum hip flexion active knee extension test deficit | Relative to uninjured in % (continuous) |
|    MDC 9.3 – 17.2°*                   |                       |
| ▪ Passive straight leg raise deficit  | Relative to uninjured in % |
|    MDC 13 – 18.0°*                    |                       |
| ▪ Passive knee extension deficit      | Relative to uninjured in % |
| ▪ Pain (and ability to perform) clinical strength tests* | Yes/no (dichotomous) |
| ▪ Force deficit for clinical strength tests* | Relative to uninjured in % |
|    MDC inner 4.9 – 5.6 kg, MDC mid 4.1 – 5.6 kg, MDC outer 6 – 6.1 kg |                       |
| Patient readiness questions           |                       |
| ▪ Rate of recovery                    | Likert scale; 1 – Not recovered at all, 2 – a little recovered, 3 – moderately recovered, 4 – recovered a lot, 5 – completely recovered (ordinal) |
| ▪ Fear of sustaining re-injury        | In percentage 0-100% recovered (continuous) |
|                                         | Likert scale; 1 – I will definitely re-injure, 2 – I will probably re-injure, 3 – Maybe I will re-injure, 4 – I will probably not re-injure, 5 – I will definitely not re-injure (ordinal) |
In percentage 0-100% chance of re-injury (continuous)

*Performed with 3 different ranges; “inner range”/“mid range”/“outer range”; MDC\(_{\text{95}}\) – Minimal detectable change (at 95% confidence interval)

Other secondary outcome variables will be assessed for normality through visual assessment of histograms and Q-Q plots -- appropriate parametric (independent t-test) or non-parametric (Mann-Whitney-U) for continuous or categorical data (Chi-Square test) will be used to determine if there is a difference at RTS between the two treatment groups. Descriptive data will be reported with mean values (±SD) or median values (IQR) for continuous variables, and as frequencies and proportions for categorical data.

**Missing data and Primary outcome consensus:**

In the event of a ‘missing’ primary outcome measure, e.g. missing discharge by sports physician but otherwise completed protocol or ‘self-decided’ return to sport nearing the end of rehabilitation, a RTS consensus has been agreed upon by the investigators.

As per previous consensus meeting:

“The date of RTS was decided:

- If final Sports specific training session (SST) and RTS discharge by SMP was performed on different days – day of SST was decided as the date of RTS

- If participant decided to play a game or train for full with team, this was noted as the self-decided RTS and a deviation from protocol.

- If a participant stopped coming or withdrew from the study, or for some reason did not complete, he was censored at the latest day he was seen at Aspetar (rehab appointment). All censored participants were decided and noted.”

**Censoring:**

| Participant | Event? | Primary outcome? | Censored? |
|-------------|--------|------------------|----------|
|             |        |                  |          |
|             |        |                  |          |
|             |        |                  |          |
|             |        |                  |          |