Supplementary Appendix to

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

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Table S1: Characteristics of participants censored for primary outcome return to Sport (RTS).

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 **Censored: 21 days from injury**
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. Withdrew 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. **Censored: 27 days from injury**
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**

HAR 79	19	Football / Professional	RTS	Stopped attending rehabilitation and did not respond to attempts at contact **Censored: 54 days from injury**
HAR 81	24	Futsal / Professional	RTS	Could not attend rehabilitation anymore due to work. **Censored: 7 days from injury**
HAR 83	29	Football / Professional	RTS	Stopped attending rehabilitation and did not respond to attempts at contact. **Censored: 5 days from injury**
HAR 87	34	Football / Professional	RTS	Called into army duty and couldn't attend rehabilitation anymore **Censored: 34 days from injury**
HAR: Hamstring rehabilitation study, RTS: Return to sport				

Table S2: characteristics of participants with consensus-based outcome due to deviation from protocol.

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

				Self-decided return to sport: 14 days from injury
HAR 73	25	Handball / Professional	RTS	Full team training before end of rehabilitation **Self-decided return to sport: 55 days from injury**
HAR 76	22	Football / Professional	RTS	Played full match before sports medicine physician return to sport assessment. **Self-decided return to sport: 16 days from injury**
HAR 77	23	Handball / Professional	RTS	Return to full team training and match play after 1 sports-specific session **Self-decided return to sport: 16 days from injury**
HAR 78	26	Handball / Professional	RTS	Played match before return to sports assessments, no show for assessments. **Self-decided return to sport: 28 days from injury**
HAR 80	25	Futsal / Professional	RTS	Delayed sports medicine physician return to sport assessment. **Date of last sport-specific session leading: 33 days from injury**
HAR 88	30	Futsal / Professional	RTS	Played multiple matches before return to sport assessments, no show for assessments. **Self-decided return to sport: 34 days from injury**
HAR 89	29	Basketball / Professional	RTS	Delayed discharged testing and did full training with the team already **Self-decided return to sport: 16 days from injury**

HAR: Hamstring rehabilitation study, DNA: did not appear, SMP: sports medicine physician, RTS: return to sport

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 10	32	Hockey / Professional	Re-injury at 2, 6, 12 months	Contact number not in use anymore.	Yes
HAR 14	30	Football / Professional	Re-injury at 2, 6, 12 months	Withdrew from study during rehabilitation phase.	Yes
HAR 20	26	Field Hockey / Professional	Re-injury at 2, 6, 12 months	No contact established after repeated attempts.	Yes
HAR 26	30	Football / Professional	Re-injury at 2, 6, 12 months	Withdrew from study during rehabilitation phase.	Yes
HAR 33	24	Handball / Professional	Re-injury at 2, 6, 12 months	No contact established after repeated attempts.	Yes
HAR 34	24	Handball / Professional	Re-injury at 2, 6, 12 months	No contact established after repeated attempts.	Yes
HAR 38	21	Football / Professional	Re-injury at 2, 6, 12 months	No contact established after repeated attempts.	No
HAR 42	31	Football / Professional	Re-injury at 6, 12 months	Left the country after RTS and could not establish contact.	No
HAR 46	19	Football / Professional	Re-injury at 2, 6, 12 months	No contact established after repeated attempts.	Yes
HAR 49	25	Futsal / Professional	Re-injury at 6, 12 months	Left the country after RTS and could not establish contact.	No
HAR 52	26	Football / Professional	Re-injury at 6, 12 months	No contact established for last two time point after repeated attempts.	No
HAR 54	18	Football / Professional	Re-injury at 12 months	No contact established for last time point after repeated attempts.	No
HAR 56	22	Handball / Professional	Re-injury at 12 months	No contact established for last time point after repeated attempts.	No
HAR 58	27	Rugby / Professional	Re-injury at 6, 12 months	Contact number not in use anymore.	No
HAR 60	26	Basketball / Professional	Re-injury at 6 months	Contact number not in use anymore. Contact at 12 months established through his previous club physiotherapist.	No

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 uninured (%)	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)						

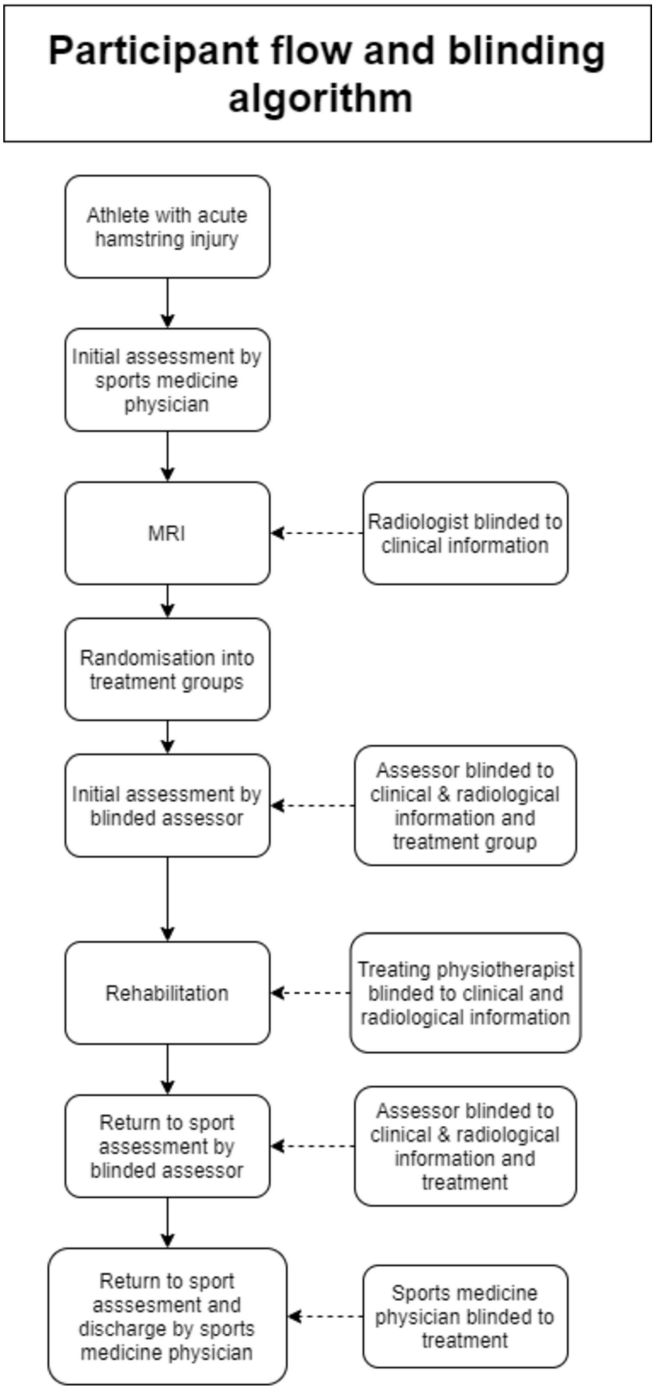
Inner	26	92.4±13.2	87–98	33	96.2±18.9	90–103
Mid	27	96.3±19.2	89–104	33	93.1±14.3	88–98
Outer	26	98.9±13.2	94–104	33	96.0±13.9	91–101
Participant readiness questions (rate of recovery 5-point Likert and continuous in %)						
Recovered a lot	8			13		
Completely recovered	19			20		
Continuous scale (0-100%)	26	94.0±8.6	91–97	33	91.8±9.2	88–95
Participant readiness questions (fear of sustaining reinjury 5-point Likert and continuous in %)						
Definitely reinjure	0			1		
Probably reinjure	2			1		
Maybe reinjure	4			5		
Probably not reinjure	8			7		
Definitely not reinjure	13			18		
Continuous scale (0-100%)	27	18.3±22.5	9–27	32	21.3±29.2	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

ASPETAR سبيتار

Patient label

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: **Sign:**		/ /201_ Days Post: **Sign:**		/ /201_ Days Post: **Sign:**		/ /201_ Days Post: **Sign:**		/ /201_ Days Post: **Sign:**	
	INJURED	*UNINJURED*	*INJURED*	*UNINJURED*	*INJURED*	*UNINJURED*	*INJURED*	*UNINJURED*	*INJURED*	*UNINJURED*
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** / *no*	*kg*	*kg* **P** / *no*	*kg*	*kg* **P** / *no*	*kg*	*kg* **P** / *no*	*kg*	*kg* **P** / *no*	*kg*
Outer range	*kg* **P** / *no*	*kg*	*kg* **P** / *no*	*kg*	*kg* **P** / *no*	*kg*	*kg* **P** / *no*	*kg*	*kg* **P** / *no*	*kg*
SLR	° **P** / *no*	°	° **P** / *no*	°	° **P** / *no*	°	° **P** / *no*	°	° **P** / *no*	°
MHFAKE	° **P** / *no*	°	° **P** / *no*	°	° **P** / *no*	°	° **P** / *no*	°	° **P** / *no*	°
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: **Sign:**		/ /201_ Days Post: **Sign:**		/ /201_ Days Post: **Sign:**		/ /201_ Days Post: **Sign:**		/ /201_ Days Post: **Sign:**	
	INJURED	*UNINJURED*	*INJURED*	*UNINJURED*	*INJURED*	*UNINJURED*	*INJURED*	*UNINJURED*	*INJURED*	*UNINJURED*
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** / *no*	*kg*	*kg* **P** / *no*	*kg*	*kg* **P** / *no*	*kg*	*kg* **P** / *no*	*kg*	*kg* **P** / *no*	*kg*
Outer range	*kg* **P** / *no*	*kg*	*kg* **P** / *no*	*kg*	*kg* **P** / *no*	*kg*	*kg* **P** / *no*	*kg*	*kg* **P** / *no*	*kg*
SLR	° **P** / *no*	°	° **P** / *no*	°	° **P** / *no*	°	° **P** / *no*	°	° **P** / *no*	°
MHFAKE	° **P** / *no*	°	° **P** / *no*	°	° **P** / *no*	°	° **P** / *no*	°	° **P** / *no*	°
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:										

HAMSTRING REHABILITATION STUDY
PROTOCOL –Aspetar“

Patient label

Weight:
Leg injured: ☐ *LEFT* ☐ *RIGHT*

WEEK:			*/ / 201_* *Sign:*			*/ / 201_* *Sign:*			*/ / 201_* *Sign:*			*/ / 201_* *Sign:*			*/ / 201_* *Sign:*			*/ / 201_* *Sign:*			*/ / 201_* *Sign:*		
STAGE	**TREATMENT**	***SETS/ REPS***	***Sets***	***Reps***	***Load***	***Sets***	***Reps***	***Load***	***Sets***	***Reps***	***Load***	***Sets***	***Reps***	***Load***	***Sets***	***Reps***	***Load***	***Sets***	***Reps***	***Load***	***Sets***	***Reps***	***Load***
1	2 LEG SQUAT *Prog: with weights*	3 x 15 3 X 8																					
1	EXERCISE BIKE *(Watt: 2x BW) 5min + 5 min*	5 mins																					
1 2	SUPINE BRIDGE 2 LEGS	3 X 12																					
1 2	SUPINE ISOMETRIC HEEL DIGS	3 X 12																					
1 2	SINGLE LEG SQUAT → 45° *Prog: with weights*	3 X 8 3 x 15																					
1 2	MANUAL RESISTED HAMSTRINGS	3 X 12																					
1 2	SOFT TISSUE	5 mins																					
1 2	ACTIVE ROM	3 x 8																					
2 3	SUPINE BRIDGE 1 LEG *2 sec up/2 sec down* *2sec up/1 sec down* *On step* *On exercise ball*	4 x 15																					
2 3	STRETCHING (SLR and PKET)	3 X 30 s																					
3	“THE EXTENDER” *Daily*	(3 x 12) x 2																					
3	“ARABESQUE/DIVER” *Every 2nd day*	3 x 6																					
3	“THE GLIDER” *Every 3rd day*	3 x 6																					
2 3	RESISTED HAMSTRINGS 1. Prone leg curl 2. Prone leg curl eccentric	 4 x 15 4 x 8																					
3	ECCENTRIC STRENGTHENING Nordic hamstring	 2 x 5 → 3 x 6																					

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

HAMSTRING REHABILITATION STUDY

PROTOCOL –Aspetar + Early Lengthening Exercises"

Patient label

Weight:
Leg injured: ☐ *LEFT* ☐ *RIGHT*

WEEK:			/ / 201_ Sign:			/ / 201_ Sign:			/ / 201_ Sign:			/ / 201_ Sign:			/ / 201_ Sign:			/ / 201_			/ / 201_ Sign:		
STAGE	**TREATMENT**	***SETS/ REPS***	***Sets***	***Reps***	***Load***	***Sets***	***Reps***	***Load***	***Sets***	***Reps***	***Load***	***Sets***	***Reps***	***Load***	***Sets***	***Reps***	***Load***	***Sets***	***Reps***	***Load***	***Sets***	***Reps***	***Load***
1	2 LEG SQUAT *Prog: with weights*	3 x 15 3 X 8																					
1	EXERCISE BIKE *(Watt: 2x BW) 5min + 5 min*	5 mins																					
1 2	SUPINE BRIDGE 2 LEGS	3 X 12																					
1 2	SUPINE ISOMETRIC HEEL DIGS	3 X 12																					
1 2	SINGLE LEG SQUAT → 45° *Prog: with weights*	3 X 8 3 x 15																					
1 2	MANUAL RESISTED HAMSTRINGS	3 X 12																					
1 2	SOFT TISSUE	5 mins																					
1 2	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* *2sec up/1 sec down* *On step* *On exercise ball*	4 x 15																					
2 3	STRETCHING (SLR and PKET)	3 X 30 s																					
2 3	RESISTED HAMSTRINGS 1. Prone leg curl 2. Prone leg curl eccentric	 4 x 15 4 x 8																					
3	ECCENTRIC STRENGTHENING Nordic hamstring	2 x 5/3 x 6																					

Criteria for progression from Stage 1 to Stage 2:	Criteria for progression from Stage 2 to Stage 3:	Criteria for progression from Stage 3 to Sports Spec Rehab:
1. Painless Single Leg Squat 2. Painless Bike, W: 2x Body Weight, 5 minutes (level 6-7)	1. Run ≥ 70% Patient-rated	1. 100% running speed 2. Painless high speed direction changes

ASPETAR

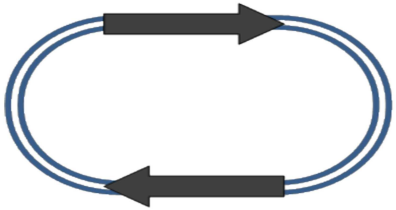
HAMSTRING REHABILITATION STUDY

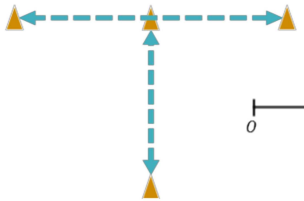
Running and sprinting protocol

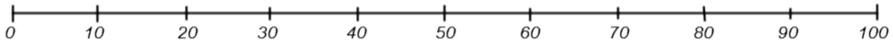
Patient label

Leg injured: ☐ *LEFT* ☐ *RIGHT*

WEEK:			/ / 201_ Sign:			/ / 201_ Sign:			/ / 201_ Sign:			/ / 201_ Sign:			/ / 201_ Sign:			/ / 201_ Sign:			/ / 201_ Sign:		
STAGE	**PREPARATION EXERCISES**	***SETS/ LAPS***	***Sets/ Laps***			***Sets/ Laps***			***Sets/ Laps***	***Best Time % max***		***Sets/ Laps***			***Sets/ Laps***			***Sets/ Laps***			***Sets/ Laps***		
2+3	Triple Extension Walk *High knee only* *(Each lap = 100m x2*	3 x 1																					
2+3	"B" Drill *High knee with "Kicks"* *(Each lap = 100m x2)*	3 X 1																					
	RUNNING ROGRESSION	***SETS/ LAPS***	***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***	***Sets/ Laps***	***Best Time***	***% max***
2+3	Walk – Jog (10 -70%) Jog –Run (70 - 100%)	3 x 4																					
3	*Comments:*		Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:		
3	Modified T-Drill (70 – 100%) (≤ 11 sec.)	3 x 1																					
	Comments		Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: 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%.*																					







Exercises and exercise progression

(see also the video supplement at 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* ***! Ensure:*** *Hips extended until 0°, i.e. straight line shoulder – hips -knees*	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.* **If needed: let the athlete stand in front of the mirror.*	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.

1 2	**MANUAL RESISTED HAMSTRINGS**	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.	I: In prone position: isokinetic resistance through ROM towards the end ROM (eccentric) II: In supine position with hip flexion: isokinetic resistance towards the end ROM (eccentric)
1 2	**SOFT TISSUE**	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.	In stage 2: Massage of inured area allowed. Maximal pain 4/10.
1 2	**ACTIVE ROM**	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.	I: Speed is increased.
Early **1 2 3** **Delayed** **3**	**"THE EXTENDER"** ***Daily***	(3x12) x2	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.	I: Speed is increased.
Early **1 2 3** **Delayed** **3**	**"DIVER"** ***Every 2nd day***	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. ***! Ensure:*** *Correct alignment of the pelvis and no movement of the LB.*	I: Weights are added: The athlete is holding manual weights or a weight bar in front of the body when performing the exercise. II: Diagonal movement: The athlete is performing a diagonal movement, trying to touch his contralateral foot.
Early **1 2 3** **Delayed** **3**	**"THE GLIDER"** ***Every 3rd day***	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.
2 3	**SUPINE BRIDGE 1 LEG** ***2 sec up/2 sec down***	4 x 15	Athlete is lying supine with the arms placed in a comfortable position. The	The athlete is instructed to push down through the heel to lift the bottom off the ground until	*I*: 1 sec up – 2 sec down (4 x 8)

			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*	II: On exercise ball or BOSU (4 x 8)
2 3	**STRETCHING (SLR and MHFPKET)**	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**	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 athletes' 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.	I: Increasing load (kg) II: Increasing load in eccentric phase
3	**ECCENTRIC STRENGTHENING Nordic hamstring exercise**	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.*	* 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

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 mm^2)	mm^2 (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)

▪ 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 *MDC_{95}: up to 76.2N*	Newton (N) (continuous)
▪ Nordic Hamstring Test Peak force imbalance between legs *MDC_{95}: up to 17%*	In % (continuous)
▪ Nordic Hamstring Test Average force per leg *MDC_{95}: up to 68.5N*	Newton (N) (continuous)
▪ Nordic Hamstring Test Average force imbalance between legs *MDC_{95}: up to 11%*	In % (continuous)
▪ Isokinetic measurements per leg: - Quadriceps concentric 60°/s - 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%*	Newton-meter (Nm) (continuous) Force deficit relative to uninjured leg (in %) (continuous)
▪ 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 *MDC 9.3 – 17.2°*	Relative to uninjured in % (continuous)
▪ Passive straight leg raise deficit *MDC 13 – 18.0°*	Relative to uninjured in %
▪ 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* *MDC_{inner} 4.9 – 5.6 kg, MDC_{Mid} 4.1 – 5.6 kg, MDC_{Outer} 6 – 6.1 kg*	Relative to uninjured in %
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) In percentage 0-100% recovered (continuous)
▪ Fear of sustaining re-injury	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"; $MDC_{(95)}$ – 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?