

## Appendix 1

### Analysis of ActiGraph data

Actigraphs are commercial 3-axis accelerometers, validated for collecting physical activity[15]. They wore the ActiGraph on the wrist of their non-dominant arm and data were analysed using ActiLife. Raw data were converted into files with 10 s epoch length for subsequent wear time validation and intensity classification. Non-wear time was defined as bouts of greater than or equal to 60mins of consecutive zero counts, allowing interruptions of up to two consecutive non-zero counts (less than or equal to 100 counts/min). Adolescents were told to record the type of activity missed by the Actigraph during non-wear. A valid day was defined as 600 valid wear-time minutes per 24 h, and four valid days were the minimum requirement for analysis. The Evenson et al.[16] cut-points were used for categorizing sedentary (0 - 100 counts/min), light (101 - 2295 counts/min), moderate (2296 - 4011 counts/min) and vigorous (4012 -  $\infty$  counts/min) intensity physical activity, as per previous research in children and adolescents[15]. The time spent in consecutive sedentary bouts of greater than or equal to 10 mins were used to calculate average weekly sedentary time. In addition, variables were computed to indicate whether or not participants met the WHO weekly physical activity recommendations (i.e. >150 mins MVPA or greater than 75mins vigorous activity).

### Pain and discomfort during exercises

46 adolescents reported pain/discomfort at least once during block 1 (5 adolescents reported it for more than 10 of the 42 exercises during block 1). 60 adolescents reported pain/discomfort at least once during block 2 (2 adolescents reported it for more than 10 sets during the 56 exercise sets during block 1). 41 adolescents reported pain/discomfort at least once during block 3 (3 adolescents reported it for during more than 10 sets during the 56 exercise sets during block 1).



# Anterior knee pain



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When you met the physiotherapist, details about your knee pain were explained; why you might have knee pain, and guidance on what you may be able to do to make it better. This leaflet provides a summary of tips and exercises, where you can look if you forget something.

### Why does your knee hurt?

The exact causes of your anterior knee pain (patellofemoral pain) can be difficult to fully understand. Often, it is thought that knee pain is caused by more forces acting on the knee joint than what it can tolerate. Some people can withstand a lot without getting knee pain, whereas, for various reasons, others may not be able to tolerate as much force. Some of the reasons for too much force/load on the knee could be e.g. too much running, too many jumps or other activities where you use your knee. Normally, the knee pain can disappear after a break for some time, but sometimes the knee pain can continue for a long time. One reason why it persists can be when people continue with the same high levels of activity that started the knee pain.

### When can you return to sport?

After the first 8 weeks of reducing the activities which aggravate your knee, it is important that you start back slowly. You should follow the guide below, and only progress to the next activity on the ladder when you no longer have knee pain during, or the next morning after the activity when you wake up (max. 2 on the pain scale out of 10 on the pain monitoring tool).

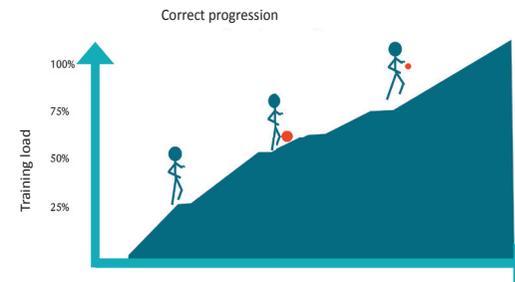
#### Activity ladder:

- Step 1. Easy walking / cycling (Lowest level)
- Step 2. Fast walking / medium to hard cycling
- Step 3. Slow running
- Step 4. Stair climbing
- Step 5. Running and jumping at medium speed.
- Step 6. Running and jumping at high speed (highest level)

When you are able to perform “Running at high speed and jumping” with no pain, or minimal pain (max 2 on the pain scale during, immediately after, and morning after activity), you can start participating in sports again.

You should start with taking part in the warm-up, and 15 minutes of the training.

Each week you can increase the amount of training by around 5 minutes, but only if you do not experience a worsening of your knee pain. When you are able to participate in the full training without knee pain for two weeks in a row, you can return to full sports participation again.



The figure above shows how to slowly increase your training to return to your sport safely. To get better, you need to increase the load gradually. Below, you see what happens if you go too fast.

If you return to sport too quickly you may need to stop again as you were not yet ready to handle these loads.



### Sports and activities in everyday life

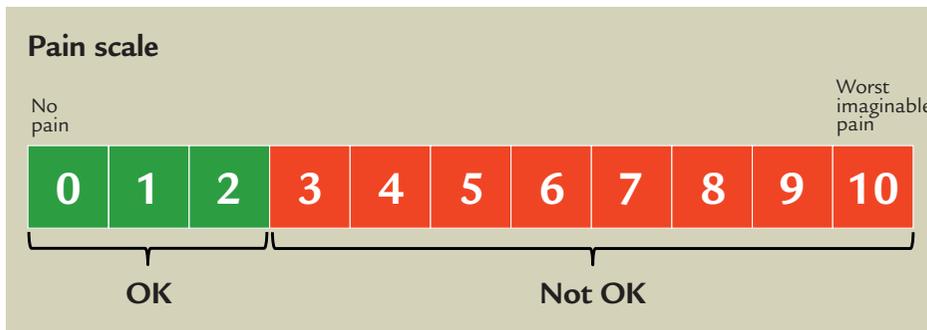
It is important to listen to your body. For example, if it hurts your knee during running, you can try to alternate between running and walking. Another example could be that you get knee pain when you walk for long distances. Then, you could try to shorten the distance and cycle part of the way instead. Remember, it is always better to try to continue being active (e.g. biking or walking) than taking the bus all the time.

The important thing is to continue doing the activities you are able to, so long as they don't cause pain higher than 2 on the pain scale during the activity. You might get sore muscles, but that is just a positive sign that you have exercised them.

### Exercises are important

During the first 4 weeks, you should perform bridges and static holds (see images) for the thigh and hip muscles. This helps keep your muscles strong without putting pressure on your knee. After 4 weeks, you should start with dynamic exercises. These exercises must be performed for 8 weeks. They are divided into 2 blocks which change after 4 weeks.

The purpose of the exercises is to make your knee and hip stronger, so your knee can tolerate more forces without getting sore. This is done by strengthening the muscles around your knee and your hip. It is very important to remember to do the exercises as often as the physiotherapist told you.



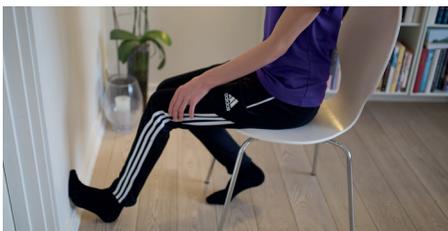
### Week 1 to 4:

You should do the bridge exercises every second day, for 3 sets of 10 repetitions. You should do the static holds every day.

**The bridge** should be performed with both feet on the floor. When you lift your body up, it is important to press down your heels. Be careful not to raise yourself too high, and sway in the back. You should perform 3 sets of 10 repetitions.



Static holds for the thighs should be performed against a wall. You should press your heels down into the floor, and should be able to feel the thigh muscle tense. The holds should be performed every day ten times for 30 seconds.



### Week 5 to 8:

**Exercises with elastic bands and your bodyweight.** The purpose of these 4 weeks is to strengthen the muscles around your hip and knees. You should not return to sports yet, but you begin to return to all of your normal activities, following the activity ladder:

- Step 1.** Easy walking/cycling (Lowest level)
- Step 2.** Fast walking/medium to hard cycling
- Step 3.** Slow running
- Step 4.** Stair climbing
- Step 5.** Running and jumping at medium speed.
- Step 6.** Running and jumping at high speed (highest level)

You should only move to the next step on the ladder should when you have little/no pain (NRS 2) during and the morning after the activity. You should perform 3 sets of all 4 exercises. The should be performed using a band that is strong enough that you can only perform 12 repetitions of the exercise before getting too tired. Each repetition must take 8 seconds, and you need to train both the left and right sides.

### Lying hip exercise

This exercise it to make your hip muscles stronger. You lie on the floor as shown in the picture below. The elastic should be around



the ankles, and then you should lift the leg around 40 cm high. It is important to point your foot straight forward when you lift the leg up. You should perform 3 sets with a band that you can only perform 12 repetitions before you are too tired. Each repeat must take 8 seconds, and you need to train both the left and right sides.



### Seated knee extension

This exercise is to make your knee stronger. You should sit on a table with an elastic band atied round the table legs. You should roll a towel under your knee and put a small towel around your ankle so the elastic does not move up your leg during the exercise. Start by extending the leg while the elastic band provides resistance. You should perform 3 sets with a band that you can only perform 12 repetitions before you are too tired. Each repeat must take 8 seconds, and you have to train both the left and right sides.



### Clam exercise

This exercise makes your hip muscles stronger. The elastic should be tied around the leg just above the knee. The hip must be bent around 60 degrees, and the knee around 90 degrees. Open your legs like a clam, while keeping the rest of the body steady.



You should perform 3 sets with a band that you can only perform 12 repetitions before you are too tired. Each repeat should take 8 seconds, and you have to train both the left and right sides.



### Semi squat

This exercise is for your knee muscles. You should stand with your feet shoulder-width apart then you squat down. This should not hurt the knees. If it hurts your knees, try not to bend down as far. Remember to bend your knees and push



your bum back. Your knees shouldn't go too far in front of your toes. You should perform 3 sets with a band length that can only perform 12 repetitions with before you are too tired. Each repeat must take 8 seconds, and you should train both the left and right sides.



### Week 9 to 12:

#### Training and Gradual Increasing Sports

The purpose of these 4 weeks is to make the muscles around the hip and knee even stronger and get ready to return to sports and your typical knee loading.

You can start returning to sports if you have reached step 6 below.

- Step 1.** Easy walking/cycling (Lowest level)
- Step 2.** Fast walking/medium to hard cycling
- Step 3.** Slow running
- Step 4.** Stair climbing
- Step 5.** Running and jumping at medium speed.
- Step 6.** Running and jumping at high speed (highest level)

You should only move to the next step on the ladder should when you have little/no pain (VAS 2) during and the morning after the activity. You have to perform 3 sets of the 4 different exercises. They should all be performed so difficult that you can only perform 12 repetitions before you are too tired. Each repeat must take 8 seconds, and you have to train both the left and right sides.

#### Standing hip abduction

This exercise makes your hip muscles stronger. You should perform the exercise using a chair. The chair is to help maintain balance. You should lift your leg out to the side while you try to keep the rest of your body steady. You must keep your foot pointing straight ahead during the exercise. You should per-



form 3 sets with a band that you can only perform 12 repetitions with before you are too tired. Each repeat must take 8 seconds, and you have to train both the left and right sides.

#### Lunges

This exercise makes your hip and knee muscles stronger. Start by standing as shown on the first picture. Then you have step forward and bend your front and back knees, while keeping the upper body straight -it must only move up and down.



You should perform 3 sets with a load that you can only perform 12 repetitions before you are too tired. Each repeat must take 8 seconds, and you have to train both the left and right sides.

#### Squat

You should stand with your feet shoulder-width apart. Then you must bend your knees to approximately 90 degree angle (as shown in the image). The exercise shouldn't hurt the knees. If it hurts, then don't bend your knees so deeply. Remember to move your bum backwards, and make sure your knees don't move too far in front of your toes. You should perform 3 sets with



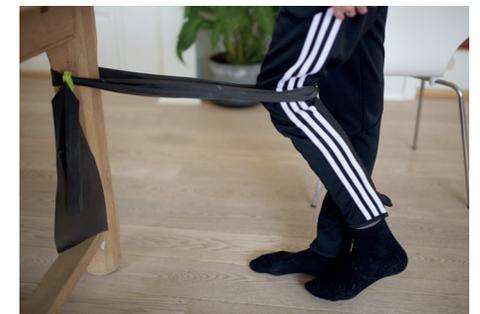
a load that you can only perform 12 repetitions before you are too tired. Each repeat must take 8 seconds, and you have to train both the left and right sides.

#### Standing hip extension

This exercise makes your hip muscles stronger. The elastic band should be fixed to a door, or around a heavy table. You have to put the elastic around your thigh, just above the backs of your knee. Push your leg back-



wards against the elastic, while holding the rest of the body still. You should perform 3 sets with a load that you can only perform 12 repetitions before you are too tired. Each repeat must take 8 seconds, and you have to train both the left and right sides.



## Main features of the intervention

### Block 1 (week 1 to 4)

- Reduce knee forces (avoid knee-aggravating activities that cause your pain)
- Static holds of the knee (every day)
- Bridge exercise (3x10, every other day)

### Block 2 (week 5 to 8)

- 4 exercises with elastic band which should be performed every second day

### Block 3 (week 9-12)

- Exercises with elastic band and your body weight



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Appendix 2B

Table 1. Overview of content during the three blocks in the intervention period. A full description of all the components can be seen in appendix 2 that contains the leaflet and additional details on the different components.

	<b>BLOCK 1 (WEEK 0-4)</b>	<b>BLOCK 2 (WEEK 5-8)</b>	<b>BLOCK 3 (9-12)</b>
<b>EDUCATIONAL COMPONENTS<sup>1</sup></b>	Factors contributing to PFP Risk of PFP Load and sport Rationale for treatment	Importance of adherence Proper exercise form Monitor and progress	Progression to sport Monitor and progress Continued exercises
<b>MODALITIES TO GRADUALLY DECREASE/INCREASE KNEE JOINT LOADS</b>	Activity modification Double limb bridge (3x10 every second day) Unilateral static holds 10x 30sec (daily)	Hip and knee exercises	Weightbearing hip and knee exercises
<b>SPECIFIC TOOLS INTRODUCED</b>	The activity ladder Pain monitoring	The activity ladder Pain monitoring	Graded return to sport, after step 6 has been reached on "activity ladder"

Additional details on the different components (patient information can be seen in the leaflet)

## **BLOCK 1**

During block 1, the physiotherapists aimed to educate the adolescents and their parents about one of the likely reasons for developing knee pain: large, intensive volumes of sport with inadequate rest between the different sessions in conjunction with high levels of physical activity during daily living. A key part of this was to not say that “sport will never be allowed”, or that “you will never be able to reach the volumes and intensities of sport you want, but that your capacity to tolerate such loads at the moment may be too low”.; “To reduce the amount of loading on your knee, we temporarily want you to avoid sports and avoid activities that aggravate your knee pain, then we want to improve the capacity of your body to tolerate loads, by making you and your muscles around the knee and hip stronger”. This gave adolescents an overall rationale and explanation of what they were going to go through for the next 12 weeks, and how to handle loads and symptom-aggravation. To combat loss of strength and muscle mass during temporary reduction in sports and physical activity they were instructed in static holds and double limb bridges and were told these exercises were important to maintain muscle strength and function (see photos of exercises and prescription in leaflet). When introducing the pain monitoring tool, the adolescents and parents were presented with this as a tool that allowed them to progress and regress activities and interpret symptoms. The aim was to teach them when activities were “ok”, and when they should consider them “not ok”. The activity ladder was based on previous trials where adolescents and parents subsequently have reported difficulty in finding a way back to full sports participation, and how they could progress activities (especially avoiding a too quick return with a subsequent boom and bust and aggravation of symptoms). They were told that the activity ladder was tool for them to teach them how to progress and regress both sports and physical activity, as well as the exercise program.

Some of the most common questions from adolescents and parents during this block was:

“How do I know if pain in the evening or morning originated from exercises or from physical activity (e.g. lots of stairs, playing during recess) sports (e.g. soccer practice).”

“How should I handle acute pain?”

“When can I return to sport?”

“What if the exercises starts to hurt?”

“What if I get stuck and can’t progress?”

“What if the exercises are too easy and pain free – can I progress to other exercises?”

Can I participate in sports activities in lesser degree if pain-free (e.g. training-session without competition) ?

“Can I expect any results by only exercising while I fully continue my sports activities?”

“I already have been through the period of avoiding sport due to my knee pain before and this strategy didn’t help me. I had even more pain and struggled to come back to my activities. Can this program help me?”

“Is it important to make the exercises as a one session of training or can be spread out during the whole day?”

## **BLOCK 2**

In block 2 they were told about the important of adhering to the exercises (to become stronger and to improve your capacity, you need to perform the exercises as much as we advise you to, in order to sufficiently stimulate the tissues we need to strengthen). They were instructed in the exercises and the physiotherapists adjusted the exercises to improve exercise form, (ie well controlled movement, at a not too fast pace, with adequate load corresponding to 10-12 repetition maximum). Here, they were also told to always perform exercises to failure and adjust load to stay in the 11-13 RM range, by adjusting the length or type of elastic band., to constantly challenge themselves to keep around 12 RM by adjusting the length of the elastic band. The physiotherapists discussed the pain monitoring tool and activity ladder again, making sure the it was used and adolescents and parents understood the purpose of it and how to use it in everyday life. Parents and adolescents were told that if any doubt about the utilization of the tools should arise, they were urges to telephone the physiotherapist.

Some of the most common questions from adolescents and parents during this block was:

“I’m pain free, can I start doing sports again?”

“Why the slow tempo?”

“What if I forget doing the exercises, should I do double or maybe do 2 sessions in two days?”

“Again, the distribution of the exercise during the day or as a one session? This mainly because of the time they needed to spend to get through the program.”

“How much pain during exercise is ok and when should I stop”?

“ I don’t get any better, maybe it’s not for me and I should stop exercising”?

### **BLOCK 3**

During block 3, they were instructed in new exercises and told these exercises closer mimics the loading patterns during the sports activity and daily functions (a rationale for choice of exercises). The physiotherapist revisited the activity ladder again and gave them information about return to sport (if they had reached step 6 on the activity ladder). They were told about the importance of continued exercises to improve the capacity to tolerate load and improve their chances of a successful return to sport and reduce relapse of knee symptoms.

Some of the most common questions from adolescents and parents during this block was: "I started training in full and started having pain again during a match the following weekend, what do I do now?"

"Should I stop doing the exercises?"

"Should I still fill out the diary?"

"Can I start doing sports tomorrow, if I still have some, but acceptable, pain during exercises, and haven't progressed to step 6 in the activity ladder?"

"I do all my exercises as prescribed but still have pain during jogging, how long should I continue before I can expect the results?"

"I'm back to sports. How often should I train to maintain the results?"

"What if I get the same problem all over again in the future? Should I start from the beginning?"

**Appendix 3: Additional Treatments and Pain Medication**

4 weeks

Type	Number of adolescents
Yes, but did not specify	5
Foot orthoses	1
Massage	1
Pain medication	25/142

8 weeks

Type	Number of adolescents
Yes, but did not specify	3
Knee sleeve	2
Pain medication	12/131

12 weeks

Type	Number of adolescents
Yes, but did not specify	3
Foot orthoses	1
Acupuncture	1
Pain medication	9/129

26 weeks

Type	Number of adolescents
Physiotherapy, unspecified	8
Knee exercise at physiotherapist	1
Massage	1
Acupuncture	1
Foot orthoses	1
Heavy resistance training	1
Pain medication	12/116

52 weeks

Type	Number of adolescents
Physiotherapy, unspecified	8
Chiropracter	1
Acupuncture	1
Knee sleeve	1
Pain Medication	16/111

Appendix 4: Differences in baseline characteristics between adolescents having a successful and non-successful outcome at the primary endpoint (12 weeks)

<b>Global Rating of chance (GROC)</b>	<b>Non-successful outcome</b>		<b>Successful outcome</b>	
Variable name	Mean	95%CI	Mean	95%CI
Age	13.0	12.6-13.4	12.6	12.4-12.9
Sex (% female)	74%	49-89%	75%	66-82%
Bilateral pain (% with bilateral pain)	84%	60-95%	71%	62-79%
Pain duration (months)	23	13-32	22	18-25
Worst knee pain past week (numeric rating scale)	6.2	4.7-7.7	6.8	6.4-7.2
Health-related quality of life* (EuroQoL 5L)	0.77	0.39-0.78	0.72	0.44-0.78
Knee-related quality of life (KOOS-QoL)	51	43-59	50	47-53
Physical activity (Moderate to vigorous activity in mins/day)	219	193-245	237	225-250
Knee extension torque (Nm/kg)	1.80	1.40-2.21	1.94	1.80-2.08
Hip abduction torque (Nm/kg)	1.20	0.94-1.46	1.24	1.17-1.32
Hip extension torque (Nm/kg)	1.24	0.99-1.49	1.16	1.09-1.24
*Presented as median and interquartile range				

<b>Return to sport</b>	<b>Non-successful outcome</b>		<b>Successful outcome</b>	
Variable name	Mean	95%CI	Mean	95%CI
Age	12.5	12.1-12.9	12.7	12.4-12.9
Sex (% female)	85%	70-93%	69%	58-78%
Bilateral pain (% with bilateral pain)	75	59-86%	71	61-80%
Pain duration	24	18-29	21	17-25
Worst knee pain past week (numeric rating scale)	6.9	6.2-7.6	6.4	5.9-6.9
Health-related quality of life* (EuroQoL 5L)	0.67	0.34-0.78	0.77	0.52-0.78
Knee-related quality of life (KOOS-QoL)	46	41-51	53	49-56
Physical activity (Moderate to vigorous activity in mins/day)	233	209-257	238	224-251
Knee extension torque (Nm/kg)	1.76	1.51-2.01	1.99	1.82-2.16
Hip abduction torque (Nm/kg)	1.23	1.06-1.40	1.24	1.15-1.32
Hip extension torque (Nm/kg)	1.04	0.91-1.17	1.24	1.15-1.33
*Presented as median and interquartile range				

<b>Global Rating of chance (GROC)</b>	<b>Non-successful outcome</b>		<b>Successful outcome</b>	
Variable name	Mean	95%CI	Mean	95%CI
% reduction in physical activity (Moderate to vigorous activity in mins/day)	11.0	-9.3-31.3	20.0	10.8-29.1

Adherence to block 1, isometric holds [% of all prescribed exercise sets]	60.7	38.0-83.4	72.3	65.1-79.4
Adherence to block 1, bridges [% of all prescribed exercise sets]	63.2	39.8-86.5	80.0	71.6-88.3
Adherence to block 2, [% of all prescribed exercise sets]	66.9	46.2-87.7	75.5	68.5-82.5
Adherence to block 3, [% of all prescribed exercise sets]	55.6	35.6-75.7	70.4	63.9-77.0